Naturalists Island.

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Kevin Coate leading W.A. Naturalists Club long-range excursion on Naturalists Island in 2006 with Hunter River in background.

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BIRDS OF NATURALISTS ISLAND, KIMBERLEY, WESTERN AUSTRALIA

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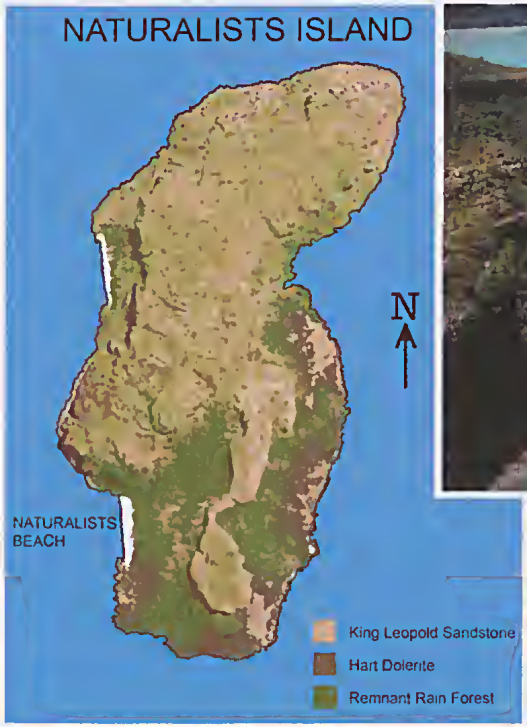
SUMMARY

This paper is based on data gathered on twenty-one visits to Naturalists Island between 1984 and 2007, which ranged from a few hours to several days during the dry season (April-October). A total of 80 bird species – 44 non passerine and 36 passerine were recorded and data on each are presented. Habitats and vegetation of the island are briefly described. Mention is made of other fauna and a shallow fringing reef.

INTRODUCTION

Naturalists Island (15°01'10"S 125°21'31"E), is located on the North West coast of Western Australia in Prince Frederick Harbour at the mouth of the Hunter River. The steeply elevated and rocky island is about 2kms by 1km in size and separated from the mainland at the narrowest point by a channel of less than half a kilometre. On low spring tides extensive mud flats and sand bars are exposed, reducing the channel to only a few hundred metres.

Members of the Western Australian Naturalists' Club leaving from Derby, first visited what was then an unnamed island in June 1984 (*The Naturalist News* – July 1984) on an adventurous long-range excursion exploring the Kimberley coast. At a number of locations biological surveys were undertaken. The Club revisited the island in May 1987, June 1992 and September 2006 (*The Naturalist News* – March 2007). Since then Naturalists Island has been used as a base for other biological surveys into the Hunter and Roe



LEFT: Map of Naturalists Island showing main geological formations and rain forest areas. Map drawn by Ian Coate. ABOVE: Naturalists Island showing Naturalists Beach. BELOW: Group from Bird Observers Club of Australia on Naturalists Island in 1993 with Prince Frederick Harbour in background.

rivers. In February 2004 the Department of Land Information Geographic Names Committee gave approval for the island to be named Naturalists Island (*The Naturalist News* – April 2004).

The geology of Naturalists Island is similar to the adjacent mainland. Approximately two thirds of the island is composed of rugged, desiccated King Leopold Sandstones and the remainder is Hart Dolerite with a capping of overlaying sandstone on the highest points toward the southern end. A few faded paintings under rock over-hangs indicate Aboriginal ties to the island.

There are two beaches on the western side of the island, both of which run in almost a north-south direction. The most southerly beach named Naturalists Beach (*The Naturalist News* – May 1990) has a good anchorage for boats, especially during periods of easterly winds. Toward the southern end of this beach during low spring tides a shallow fringing reef is bared, exposing an extra-ordinary array of colourful gorgonian corals, sponges, molluscs, crabs, fish and other interesting marine life as yet undocumented. Cloudy water caused by the continually changing tides, usually obscures the vision of the reef. From observations, this reef is typical of many other little known fringing reef systems connected to islands along the Kimberley coast, which with future studies will most likely prove to be of major interest to marine biologists. There are two smaller beaches on the south-east side of the island, which face the Hunter River.

A gully of dense remnant rain forest extends upwards in a north-easterly direction from Naturalists Beach to a saddle between two hills overlooking the mainland. The hill on the west side of the saddle is 169m above sea level, and that on the east side is slightly lower at 159m. From the summit of these hills, spectacular views can be seen over Prince Frederick Harbour and toward the mouth of the Hunter and Roe rivers. During the wet season water flows down this gully, which has been known to contain pools until the end of May. On 29 April 2006 water was flowing strongly from springs near the head of the gully. Another pocket of rain forest mixed with pandanus is situated above the beaches on the south-east side of the island.

There are two small seepages that at times exude fresh water until mid June. One is at the base of a sandstone cliff on the western side of the island between the two beaches, and the other in a dolerite headland on the shoreline at the southern end. There could be a further seepage above a beach on the south-east side of the island.

Vegetation on Naturalists Island is diverse. Naturalists Beach mainly consists of *Spinifex longifolius* (Beach Spinifex),

Canavalia rosea (Beach Bean) and *Ipomoea pes-caprae* (Beach Morning Glory). The remnant rain forest behind the beach and up the gully leading to the saddle, includes *Albizia lebbek* (Rain Tree), *Mallotus dispersus*, *Sterculia quadrifida*, *Melia azedarach* (White Cedar), *Lysiphyllum cunninghamii* (Kimberley Bauhinia), *Ficus racemosa* (Stem Fruited Fig), *Pandanus* sp., *Aidia racemosa*, *Flagellaria indica* (Supplejack), *Adenia heterophylla*, *Cappris* sp., *Jasminum didymum* (Wild Jasmine), *Celtis philippensis*, *Abrus precatorius* (Crabs Eye Bean), *Geodorom neocaledonicum* (a terrestrial orchid growing on red volcanic soil) and *Auricularia* sp. (Ear Fungus) attached to vines. Vegetation over the King Leopold sandstone slopes and hills, include *Plectrachne* sp. (Hummock Grass), *Eucalyptus miniata* (Woollybutt), several with hollows hosting *Cymbidium canaliculatum* (epiphytic orchid), *Callitris intratropica* (Cypress Pine), *Ficus platypoda* (Common Rock Fig), *Grevillea refracta* (Silverleaf Grevillea), *Grevillea wickhamii* (Wickham's Grevillea), *Grevillea agrifolia* (Blue Grevillea), *Acacia adenogonia*, *Hibbbertia ledifolia*, *Calytrix exstipulata* (Turkey Bush), *Bossiaea bossiaeoides* and *Xanthostemon paradoxus*. For two years after a severe fire in 1992 *Trachymene dendrothrix* and other fire regenerative herbs and grasses dominated over the sandstone. Over the Hart Dolerite there is rank grassland consisting of *Sorghum* sp. and other grasses inter mixed with *Cochlospermum fraseri* (Kapok Tree), *Brachychiton viscidulus* (Kimberley Rose), *Corymbia* sp. and *Terminalia* sp. Some mangroves grow on the north-eastern side of the island.

ANNOTATED BIRD SPECIES LIST

This list is a summary of data gathered on twenty-one visits to Naturalists Island between 1984 and 2007, which ranged from a few hours to several days during the dry season (April–October). Names accord with those used by Johnstone (2001).

MEGAPODIIDAE

Orange-legged Scrubfowl – ***Megapodius reinwardt***

Moderately common. Resident in remnant rain forest areas behind Naturalists Beach. Their distinctive screaming and chuckling calls are often heard shortly before dawn and on moonlit nights.

Breeding. Two nest mounds (one more accessible than the other is on the shore-line above Naturalists Beach).

PHASIANIDAE

Brown Quail – ***Coturnix ypsilophora***

Scarce. A flock (about 8) on 10 June 1984. Although only recorded on one occasion, it is not uncommon to find Brown Quail on other Kimberley islands with long grass.

PHALACROCORACIDAE

Pied Cormorant – ***Phalacrocorax varius***

Scarce. One resting on the shoreline on 10 September 2006.

PELECANIDAE

Australian Pelican – ***Pelecanus conspicillatus***

Scarce. Two resting on Naturalists Beach on 25 May 1987.

ARDEIDAE

White-faced Heron – ***Ardea novaehollandiae***

Moderately common. Four on rocks on eastern side of island on 25–26 May 1987. One on 2 June 1992 and 10 September 2006.

Eastern Reef Egret – ***Egretta sacra***

Common. Both white and grey colour phases.

ACCIPITRIDAE

Osprey – ***Pandion haliaetus***

Moderately common. One or two on most visits.

Square-tailed Kite – ***Hamirostra isura***

Scarce. One observed by JN Talbot, flying at canopy level above remnant rain forest and eucalyptus covered slopes, to catch and eat two small birds on 25 May 1987.

Occasionally recorded flying low over mangals in the nearby Hunter River.

Whistling Kite – ***Haliastur sphenurus***

Uncommon. One on 10 June 1984 and 28–29 May 1996.

Brahminy Kite – ***Haliastur indus***

Moderately common. 1 or 2 on most visits.

Breeding. A pair with a nest in a tree against a cliff face at the northern end of Naturalists Beach on 2 May 2000.

Grey Goshawk – ***Accipiter novaehollandiae***

Scarce. One in remnant rain forest gully up from Naturalists Beach on 2 June 1992.

Brown Goshawk – ***Accipiter fasciatus***

Occasionally seen on edges of the rain forest and eucalyptus woodland.

Little Eagle – ***Aquila morphnoides***

Uncommon. One on 4 June 1985, 25 May 1987, 4 June 1993 and 28–29 May 1996. In 1993 a Brahminy Kite and a Little Eagle were seen to lock talons in an aerial fight above Naturalists Beach.

Wedge-tailed Eagle – ***Aquila audax***

Uncommon. One flying around cliffs on several occasions on 21–22 June 1984.

White-bellied Sea-Eagle – *Haliaeetus leucogaster*

Moderately common. One or two in the vicinity on most visits.

FALCONIDAE

Brown Falcon – ***Falco berigora***

Uncommon. One on 10 June 1984 and 4 June 1985.

SCOLOPACIDAE

Whimbrel – ***Numenius phaeopus***

Moderately common. In small flocks (4–8) on Naturalists Beach and sand banks on east side at low tide.

Common Greenshank – ***Tringa nebularia***

Scarce. One on 2 June 1992.

Common Sandpiper – ***Tringa hypoleucos***

Uncommon. Three at southern end on 10 September 2006.

BURHINIDAE

Beach Stone-Curlew – ***Esacus neglectus***

Moderately common. On one occasion, a pair was observed on Naturalists Beach feeding on the abundant hermit crabs. They appeared selective before picking one up and beating it against a rock until the crab was ejected from its mollusc-shell home. Similar beaches on nearby islands often have a resident pair.

HAEMATOPODIDAE

Pied Oystercatcher – ***Haematopus longirostris***

Moderately common. 1–3 on shore-line and rocks on most visits. Often heard at night.

Sooty Oystercatcher – ***Haematopus fuliginosus***

Moderately common. Not recorded as often as Pied Oystercatcher on Naturalists Island – more common elsewhere.

GLAREOLIDAE

Australian Pratincole – ***Stiltia isabella***

Uncommon. One on Naturalists Beach on 21–22 June 1984. It was remarkably unafraid and came to within a few metres of us. Several on 28–29 May 1996.

LARIDAE

Silver Gull – ***Larus novaehollandiae***

Scarce. One on 22 June 1984.

Caspian Tern – ***Sterna caspia***

Scarce. An occasional single bird flying past.

Lesser Crested Tern – ***Sterna bengalensis***

Moderately common. Flying close inshore and occasionally resting on rocks at southern end

Crested Tern – ***Sterna bergii***

Uncommon to moderately common. Flying close inshore and occasionally resting on rocks with Lesser Crested Tern at southern end.

COLUMBIDAE

Emerald Dove – ***Chalcophaps indica***

Uncommon to moderately common. One or two in remnant rain forest gully.

White-quilled Rock Pigeon – ***Petrophassa albipennis***

Moderately common (2–6) on sandstone and around cliff faces.

Bar-shouldered Dove – ***Geopelia humeralis***

Common in and around the fringes of the rain forest.

Rose crowned Fruit-Dove – ***Ptilinopus regina***
Moderately common (2–3) in remnant rain forest. Some times difficult to locate in the canopy – their distinctive accelerating call usually heard on most visits.

Pied Imperial Pigeon – ***Ducula bicolor***
Moderately common. A small flock (7) on Naturalists Island in May 1996.

Unlike other populations in Northern Australia, the Kimberley population does not migrate. However they occasionally form large flocks. A flock (at least 250) was on the Coronation Islands to the west of Prince Frederick Harbour on 2 June 1993. A similar size flock on St Andrew Island in St George Basin to the south on 5 June 1993. A flock (at least 60) was at the entrance to the Hunter River opposite Naturalists Island on 21 July 1997.

PSITTACIDAE

Red-tailed Black Cockatoo – ***Calyptorhynchus banksii***
Scarce. A flock (about 10) on 2 June 1992. Flocks (up to 20) seen from Naturalists Island on the mainland.

Sulphur-crested Cockatoo – ***Cacatua galerita***
Uncommon. Two on 21–22 June 1984 and 10 September 2006.

Red-winged Parrot – ***Aprosmictus erythropterus***
Scarce. Several on 25 May 1987.

CUCULIDAE

Brush Cuckoo – ***Cacomantis variolosus***
Scarce. One on 8 August 2005.

Horsfield's Bronze-Cuckoo – ***Chrysococcyx basalis***
Scarce. One on 21–22 June 1984.

CENTROPODIDAE

Pheasant Coucal – ***Centropus phasianinus***
Moderately common. Heard calling more often than seen.

STRIGIDAE

Barking Owl – ***Ninox connivens***
Scarce. One calling from remnant rain forest gully behind Naturalists Beach on 25 May 1987.

Boobook Owl – ***Ninox novaeseelandiae***
Moderately common. One calling on several visits.

PODARGIDAE

Tawny Frogmouth – ***Podargus strigoides***
Scarce. One flushed from a small tree (*Corymbia* sp) growing in soil over Hart Dolerite at southern end on 4 June 1985.

HALCYONIDAE

Blue-winged Kookaburra – ***Dacelo leachii***
Uncommon. One on 4 June 1985, one on 1 May 2005 and two on 7 August 2005.

Sacred Kingfisher – ***Todiramphus sanctus***
Moderately common.

MEROPIDAE

Rainbow Bee-eater – ***Merops ornatus***
Moderately common.

PITTIDAE

Rainbow Pitta – ***Pitta iris***
Moderately common (1–2) in remnant rain forest gully above Naturalists Beach.

PARDALOTIDAE

Striated Pardalote – ***Pardalotus striatus***
Scarce. Several in eucalyptus woodland on 20 June 2004.

ACANTHIZIDAE

Weebill – ***Smicrornis brevirostris***
Uncommon. Small flock (5) on 25 May 1987 and (3) on 4 September 2004.

Green-backed Gerygone – ***Gerygone chloronotus***
Scarce. One on 21–22 June 1984 – probably more common than recorded.

MELIPHAGIDAE

Brown Honeyeater – ***Lichmera indistincta***
Very common on most visits.

Red-headed Honeyeater – ***Myzomela erythrocephala***
Uncommon (an occasional visitor) – probably more common in the few mangroves on the eastern side.

White-lined Honeyeater – ***Meliphaga albilineata***
Moderately common. Six (mainly immature) on 27 May 1987.

White-gaped Honeyeater – ***Meliphaga unicolor***
Common on most visits.

White-throated Honeyeater – ***Melithreptus albogularis***
Common. Attracted to *Eucalyptus miniata* blossom.

Little Friarbird – ***Philemon citreogularis***
Moderately common on most visits.

Silver-crowned Friarbird – ***Philemon argenticeps***
Common.
Breeding. A pair feeding young in a nest in *Eucalyptus miniata* on a cliff-face on the northern end of Naturalists Beach on 10 June 1984.

Banded Honeyeater – ***Cissomela pectoralis***
Scarce. Several on 25 May 1987 – attracted to *Eucalyptus miniata* blossom.

Rufous-throated Honeyeater – ***Conopophila rufogularis***
Scarce. Several in eucalyptus woodland on 28–29 May 1996.

PETROICIDAE

White-browed Robin – ***Poecilodryas superciliosa***
Scarce. One in remnant rain forest gully behind Naturalists Beach on 4 June 1985.

PACHYCEPHALIDAE

Rufous Whistler – ***Pachycephala rufiventris***

Uncommon. Two on 25 May 1987 and 4 September 2004.

DICRURIDAE

Broad-billed Flycatcher – ***Myiagra ruficollis***

Scarce. One in rain forest gully behind Naturalists Beach on 28–29 May 1996.

Leaden Flycatcher – ***Myiagra rubecula***
Common on most visits.

Shining Flycatcher – ***Myiagra alecto***
Scarce. One in rain forest gully behind Naturalists Beach on 29 April 2006.

Rufous Fantail – ***Rhipidura dryas***
Uncommon. One on 25 May 1987 and two 10 September 2006.

Northern Fantail – ***Rhipidura rufiventris***
Common on most visits.

Spangled Drongo – ***Dicrurus bracteatus***
Uncommon. One on 4 June 1985, 2 on 4 September 2004 and 2 on 8 August 2005 – in the gully on the edge of remnant rain forest behind Naturalists Beach.

CAMPEPHAGIDAE

Black-faced Cuckoo-shrike – ***Coracina novaehollandiae***

Common on most visits.

Breeding. One on a nest situated in the fork of a horizontal limb of a *Eucalyptus miniata* at the northern end of Naturalists Beach in May 1987.

White-breasted Cuckoo-shrike – ***Coracina papuensis***
Moderately common.

White-winged Triller – ***Lalage tricolor***
Uncommon. Several on 10 June 1984 and 25 May 1987.

Varied Triller – ***Lalage leucomela***
Moderately common to common.

Breeding. A pair with a nest in the horizontal fork of a branch of a small *Lysiphyllum cunninghamii* tree in remnant rain forest behind Naturalists Beach. Observed sitting over 2 days on 3–4 June 1993. Rarely recorded breeding in the Kimberley. This may be the first breeding record.

ORIOLIDAE

Yellow Oriole – ***Oriolus flavocinctus***

Scarce. A pair in remnant rain forest behind Naturalists Beach on 21 June 1984.

ARTAMIDAE

White-breasted Woodswallow – ***Artamus leucorhynchus***

Scarce. Several on 28–29 May 1996.

Black-faced Woodswallow – ***Artamus cinereus***
Scarce. A small flock (about 8) on 5 May 2002.

Little Woodswallow – ***Artamus minor***
Moderately common around cliff-faces.

CRACTICIDAE

Pied Butcherbird – ***Cracticus nigrogularis***
Scarce. One on 4 June 1985.

PTILONORHYNCHIDAE

Great Bowerbird – ***Ptilonorhynchus nuchalis***
Common on all visits. Several bowers on the edge and in the remnant rain forest gully above Naturalists Beach.

In May 1993 it seemed that the late 1992 wild fire, having burnt off leaf litter exposing snail shells, had benefited at least one male. There were almost double the number of large white snail shells mounded up at the entrance to its bower, since the previous visit in June 1992.

HIRUNDINIDAE

Tree Martin – ***Hirundo nigricans***
Moderately common.

Fairy Martin – ***Hirundo ariel***
Uncommon. Remains of old nests beneath a rock ledge near the top of the hill on north side of gully in 1993.

ZOSTEROPIDAE

Yellow White-eye – ***Zosterops luteus***
Scarce. Several on 25 May 1987.
Probably more common on the eastern side, where there are some mangroves.

SYLVIIDAE

Golden-headed Cisticola – ***Cisticola exilis***
Moderately common. 1–3 on grassed areas over dolerite at southern end of island.

DICAEIDAE

Mistletoebird – ***Dicaeum hirundinaceum***
Moderately common.

DISCUSSION

A total of 80 species (44 non passerine and 36 passerine) were recorded on Naturalists Island. Due to extremely rugged terrain, bird observations were mainly restricted to the areas behind the beaches, the rain forest gully and the Hart Dolerite areas at the southern end. Although considerable work has been done recording birds on the island, there is no doubt that during different seasons other species would be found. These are likely to include Red-capped Plover (*Charadrius ruficapillus*), Peaceful Dove (*Geopelia striata*), Rainbow Lorikeet (*Trichoglossus haematodus*), Varied Lorikeet (*Trichoglossus versicolor*), Little Bronze-cuckoo (*Chrysococcyx minutillus*), Common Koel (*Eudynamys scolopacea*), Dollar Bird (*Eurystomus orientalis*), Blue-faced Honeyeater (*Melithreptus cyanotis*), Little Shrike-thrush (*Colluricincla megarhyncha*),

Sandstone Shrike-thrush (*Colluricincla woodwardi*), Olive-backed Oriole (*Oriolus sagittatus*), Figbird (*Sphecotheres viridis*) and Torresian Crow (*Corvus orru*).

Access over much of the island can be difficult, unless there has been a fire. This is largely due to a dense covering of hummock grass that builds up over jumbled sandstone boulders. Caution is advised when walking over sandstone, as many large seemingly stable boulders can un-expectantly tip.

Fire is a major factor detrimental to the island's bird population. Although infrequent, un-controlled wild fires, such as one that occurred in the late dry season of 1992 (probably caused by a lightning strike) alters habitat, particularly remnant rain forests. Prior to 1992 it had been many years since the island suffered a major fire, evidenced by the very dense build up of *Plectrachne* sp. (Hummock Grass) and a number of fire sensitive *Callitris intratropica* (Cypress Pine) growing on the slopes. On a visit in May 1993 (with the Bird Observers Club of Australia), following the fire of 1992, the island was devoid of its usual coverage of hummock grass. With the exception of a few Cypress pine trees on the side of cliffs that escaped the blaze, all others were dead. *Eucalyptus miniata* (Woollybutt) being more fire resistant, survived, even though their crowns were burnt. Fortunately the fire did not fully penetrate the remnant rain forest gully behind Naturalists Beach, although several large trees on the outer edge were destroyed reducing it in size.

Since the 1990s Naturalists Island has become increasingly popular as a stopover for luxury cruise boats on ECO tours, when exploring the Hunter and Roe river region. Naturalists Beach is now also used as a touch-down and pick-up point for helicopters transferring passengers from these boats to Mitchell Falls on the Mitchell Plateau. These activities mainly occur during the dry season. There is little doubt that at times they are intrusive and disruptive to some birdlife in the rain forest behind the beach area – for example Orange-legged Scrubfowl and Beach Stone-Curlew which have been observed to temporally leave the area.

Other Fauna

The Pale Field Rat (*Rattus tunneyi*) was common in warrens behind Naturalists Beach in 2005 and 2006. In previous years other warrens recorded higher up on the edges of the rain forest gully, may have belonged to the same species. Single burrows on the slopes and around cliff faces may be worth further investigation. Scats of the Short-beaked Echidna (*Tachyglossus aculeatus*), first noticed in 1984, are occasionally found in the sandstone. Saltwater Crocodiles (*Crocodylus porosus*) inhabit the surrounding waters and sometimes come ashore on the island.

An unidentified Monitor (*Varanus* sp.) was seen above the beach on the eastern side of the island in May 1987. A Common Tree Snake (*Dendrelaphis punctulatus*) was identified in the rain forest gully behind Naturalists Beach in June 1984 and several unidentified species of Skink have also been seen. Common Sheathtail Bat (*Taphozous georgianus*) are occasionally found sheltering in the cavity of a prominent rock on Naturalists Beach. Little Red Flying-fox (*Pteropus scapulatus*) fly from the mainland and feed on flowering *Eucalyptus miniata* (Woollybutt) trees. Common Crow Butterflies (*Euploea core*) are common under rain forest vegetation in the gully behind Naturalists Beach and a large Orb Weaver Spider, (most likely *Nephila maculata*) is commonly encountered in the rain forest gully.

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THE IMPACT OF FIRE UPON THE SIZE AND FLOWERING OF THREE HONEY POSSUM FOODPLANTS AT THE WESTERN END OF THE FITZGERALD RIVER NATIONAL PARK, WESTERN AUSTRALIA

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ABSTRACT

The Honey Possum (*Tarsipes rostratus*) is a tiny marsupial found only in the south-west of Western Australia. It feeds exclusively upon pollen and nectar. The mediterranean climate of this area means that the area is prone to recurrent fires. Fire can often have a severe impact on the availability of resources required by small mammals for their survival.
During a long-term study of the impact of fire upon the Honey Possum in the Fitzgerald River National Park (FRNP) on the south-west coast of Western Australia, the impact of fire upon size and flowering of three of its preferred foodplants was studied.
All three species of foodplants were recorded at four study areas, last burnt some 5, 13, 23 and > 50 years earlier. Despite substantial variation between plants at each area, those areas unburnt for longer had taller plants bearing more inflorescences. The results obtained clearly indicate that fire can have a severe impact of the availability of the inflorescences favoured by these small marsupials. The increase in Honey Possums with increasing time since fire, and maximal captures in areas unburnt for some 30 years, corresponds well to the availability of foodplants in these areas.

INTRODUCTION

The Honey Possum (*Tarsipes rostratus*) is a tiny (7–12 g) highly specialised marsupial that feeds exclusively upon pollen and nectar to meet all of its nutritional requirements. A high metabolic rate means that they need to feed daily (Renfree *et al.* 1984). Endemic to the south west of Western Australia, the Honey Possum inhabits coastal sand-

plain heathlands rich in the proteaceous and myrtaceous species that provide most of the inflorescences upon which it feeds.

There are several threats to the vegetation that provides the foodplants and cover upon which the Honey Possum depends for its survival. These threats may include clearance and fragmentation, inappropriate fire regimes, decreased rainfall, and the root-rot fungus *Phytophthora cinnamomi*. Some of these threats have been studied in areas inhabited by Honey Possums on the south coast of Western Australia, including the Fitzgerald River National Park (Wooller *et al.* 2008, Everaardt 2003, Wooller *et al.* in prep.) and the Scott National Park (Bradshaw *et al.* 2007).

Fire abruptly, and often severely, modifies small mammal habitat by reducing food supply and removing cover (Bowland and Perrin 1988), and the responses to fire of many animals are mediated by the changes to these critical resources (Driessen *et al.* 1991). It is not surprising, therefore, that the Honey Possum, a non-flying small mammal that is completely dependent upon a limited suite of nectar- and/or pollen rich plants to meet all of its nutritional requirements, is severely impacted by fire. Thus, the reduction or absence of flowering foodplants might contribute to the observed reduction in the capture rates of Honey Possums following fire (Wooller *et al.* in prep., Everaardt 2003).

The foodplants most frequently visited by Honey Possums at the western end of the Fitzgerald River National Park were *Banksia nutans* in summer and *B. baueri* in winter (Everaardt 2003). Both of these plants have flowers that are rich in pollen and nectar, vital to the Honey Possum's survival. This paper reports information on the heights and flowering of these two potential foodplants, as well as another potential foodplant (*Dryandra plumosa*), in relation to the time since the vegetation was last burnt.

METHODS

Study area

The Fitzgerald River National Park is located on the central south coast of Western Australia. It is one of the largest and most botanically rich national parks in Australia, and covers an area of almost 330,000 ha (Moore *et al.* 1991).

The study sites were located at the western end of the Park (Figure 1). The trapping grids were established within four areas with different fire histories. At the time of this study, Area 1 (Grids 1a and 1b) was last burnt more than 50 years ago. Long-term residents of the area confirm that this area has had no fires in living memory, and the vegetation in this area appears to have changed little over the 19 years of research in the area (R.

Clockwise from top: *Banksia baueri*. Photographed in garden at Sawyers Valley, Eric McCrum. *Banksia nutans*. Photographed in Two Peoples Bay, Eric McCrum. Honey possum in Scott National Park. Photo Don Bradshaw. *Dryandra plumosa*. Photographed in Fitzgerald River National Park, Margaret Pieroni.

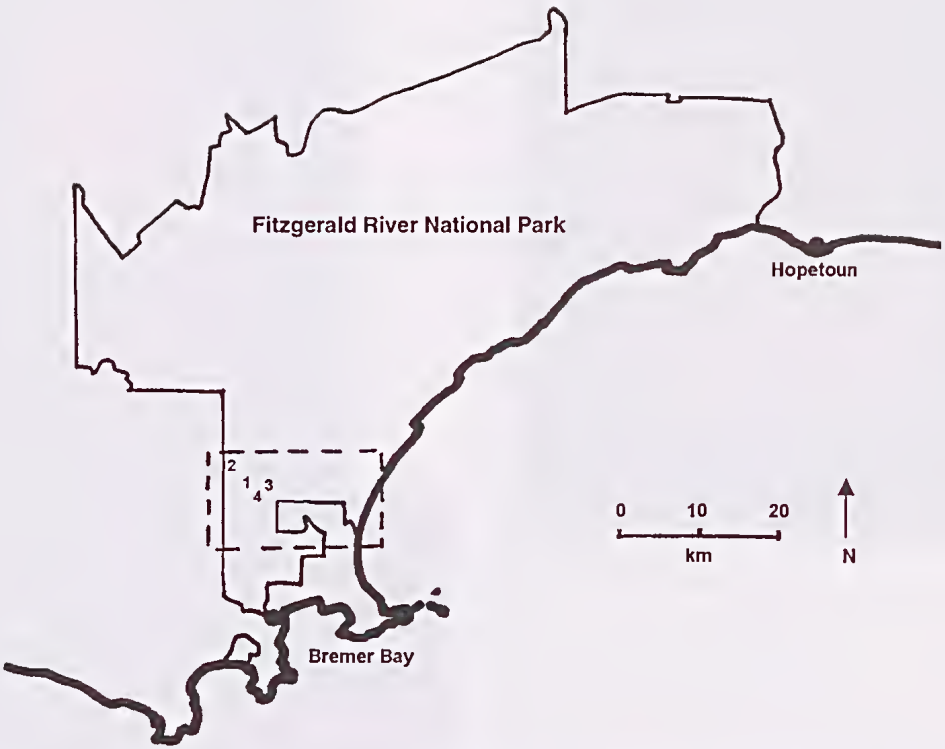


Figure 1. Location of trapping areas within the Fitzgerald River National Park. For further details on distances between trapping areas and between grids see Everaardt (2003).

Wooller, personal communication). This is supported by the maturity of the vegetation and the senescence of some of the plants in the grids. A similar fire history was arrived at based on aerial photographs of the area (Moore *et al.* 1991). Area 2 (Grid 2) was last burnt in a prescribed management burn in March 1980. The 1980 fire was a low intensity ("cool") burn of a strip of vegetation between two firebreaks some 200 to 300 m apart, with long unburnt vegetation remaining unburnt on both sides throughout the study. There was no indication of fire before 1980 in the immediate area (Saffer 1998) and prior to this fire Area 2 appears to have been unburnt for at least 37 years (Moore *et al.* 1991).

Area 3 (Grids 3a and 3b) was last burnt in December 1989 following a series of lightning strikes over a two-week period. Some 37 % of the Park was burnt in these high intensity ("hot") wildfires, the largest on record

for the Park (McCaw *et al.* 1992). Prior to the 1989 fires, it was estimated that the area had been unburnt for at least 32 years (Moore *et al.* 1991). Area 4 (Grids 4a and 4b) was last burnt in May 1998. The fire started as a prescribed management burn for fuel reduction, but became more widespread than expected. The intensity of the fire was variable as it travelled some 8 to 10 km along a front from a few hundred metres to 1–2 km wide. Prior to this fire, Area 4 was estimated to have been unburnt for at least 51 years (Moore *et al.* 1991).

Size-class distributions of three potential foodplants

The height of 50 plants each of *Banksia baueri*, *B. nutans*, and *Dryandra plumosa* at six trapping grids was measured in March 2003. At this time, the age of the vegetation at the grids ranged from nearly five years old (Grids 4a and 4b) to > 50 years old (Grids 1a and 1b). These three foodplants featured prominently in the study of pollen loads taken from Honey Possums, reported in Everaardt 2003, and were present in samples taken from individuals caught in the most recently burnt Area 4, as well as from animals caught in areas longer unburnt. The two banksia species regenerate only from seed, and grow only slowly, whilst *D. plumosa* can regenerate from an underground lignotuber, as well as from seed (George 1984).

The heights of the first 50 plants of each of these species encountered at each grid were measured to ± 1 cm. The only exception to this protocol was at dense and long unburnt Grids 1a and 1b, where only 30 plants of *B. baueri* and *B. nutans* were measured, and then only plants that could be accessed without undue trampling of the vegetation; this minimised the risk of vegetation damage and disturbance to fauna. In addition, only 19 *D. plumosa* plants were visible from the tracks at Grid 1a, and only 4 plants at Grid 1b; thus, only these 23 plants were measured at this area.

Flowering indices of three potential foodplants

A flowering index was recorded for each of the species whose heights were measured. This flowering index was the number of inflorescences (developing, fresh, and those from previous seasons) on each plant measured. Those plants that had yet to flower were recorded as such. Developing, fresh and older inflorescences were recorded because the study was completed at the beginning of autumn when at least two of the three plant species were not in their normal flowering period; *Banksia baueri* is a winter flowering plant and *B. nutans* a summer flowering plant, whereas *Dryandra plumosa* flowers for much of the year. Only some indication of whether plants had flowered was sought,

accordingly no detailed statistical analyses were performed.

RESULTS

Size-class distributions of three potential foodplants

Table 1 shows the median and mean (± 1 S.E.) height for the *Banksia baueri*, *B. nutans* and *Dryandra plumosa* plants measured at each of the seven trapping grids. In general, the median and mean heights of all three species were similar at trapping grids in the same area (Table 1). All three species were taller in areas longer unburnt (Table 1).

Figure 2 shows the percentage frequency distributions of seven height categories for each of the foodplant species measured. Almost all plants sampled at Grids 4a and 4b, and also at Grids 3a and 3b, were less than 76 cm in height, and all were less than 101 cm (Figure 2). In contrast, at Grids 1a and 1b, 80 % or more of the *B. baueri* plants and more than 90 % of *B. nutans* plants sampled were taller than 75 cm, and all of the *D. plumosa* plants were taller than 50 cm (Figure 2). Plants at Grid 2 were, on average, similar in height to those at Grids 1a and 1b (Figure 2).

Flowering indices of three potential foodplants

Shown in Figure 3 are the percentage frequency distributions of the indices of flowering for the *Banksia baueri*,

Table 1. The median and mean (± 1 S.E.) heights of the *Banksia baueri* (top), *B. nutans* (centre) and *Dryandra plumosa* (bottom) plants measured in March 2003.

Grid	Years since last burnt	Median height (cm)	Mean (± 1 S.E.) height (cm)
Banksia baueri			
1a	> 50	98.0	97.4 ± 3.1
1b	> 50	87.0	86.9 ± 2.1
2	23	84.0	83.2 ± 1.9
3a	13	55.5	54.8 ± 1.3
3b	13	49.0	50.9 ± 1.7
4a	5	38.0	38.4 ± 1.1
4b	5	42.0	41.9 ± 1.1
Banksia nutans			
1a	> 50	119.5	123.6 ± 4.3
1b	> 50	110.5	112.0 ± 4.0
2	23	83.0	84.9 ± 2.1
3a	13	50.0	51.3 ± 1.7
3b	13	45.0	47.2 ± 1.3
4a	5	27.5	28.6 ± 0.7
4b	5	27.0	27.1 ± 0.7
Dryandra plumosa			
1a	> 50	70.0	78.0 ± 5.4
1b	> 50	78.0	84.3 ± 14.0
2	23	70.5	70.5 ± 2.4
3a	13	45.5	48.3 ± 1.9
3b	13	42.5	42.6 ± 1.5
4a	5	30.0	31.0 ± 1.0
4b	5	25.0	27.6 ± 1.3

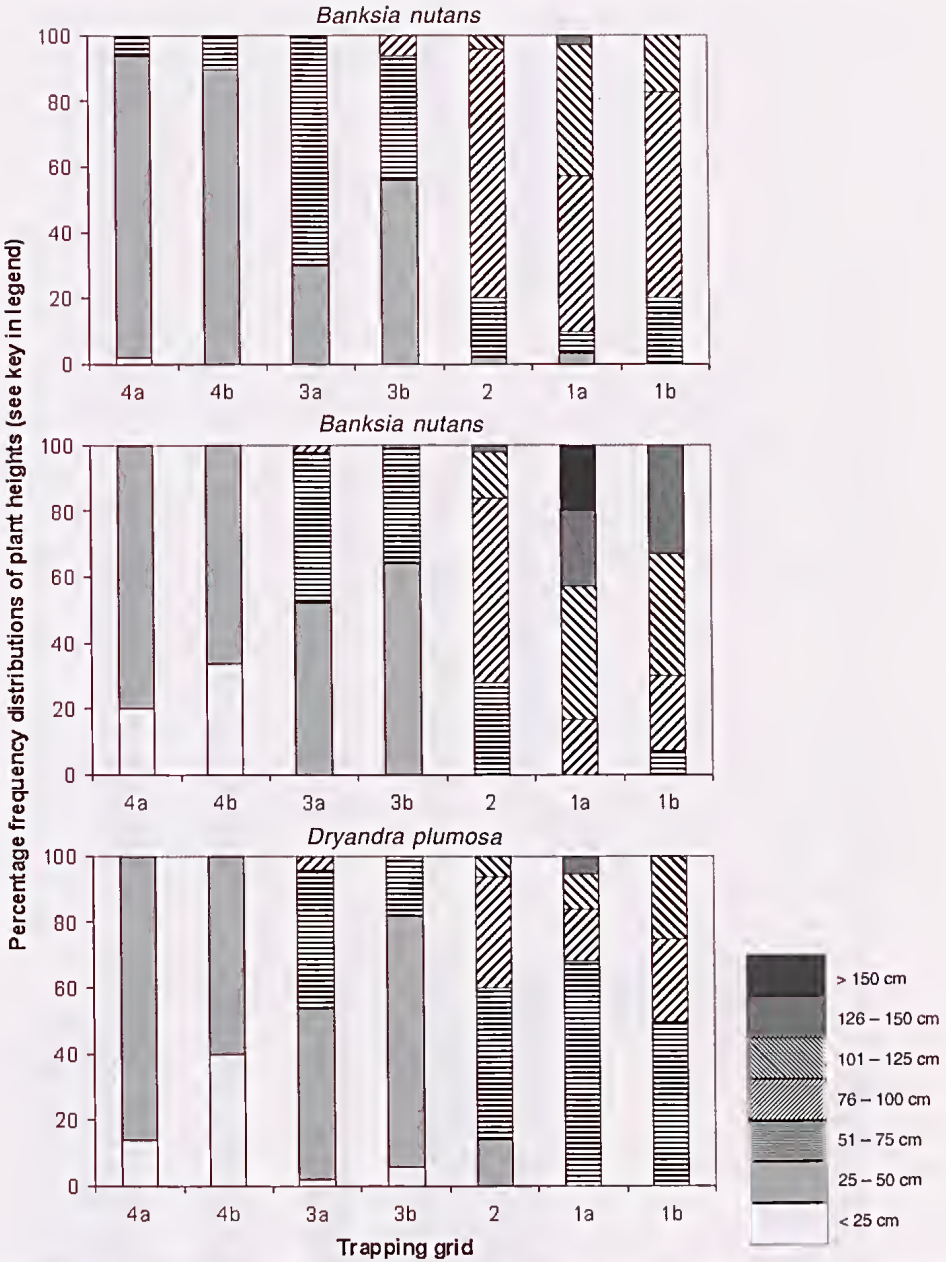
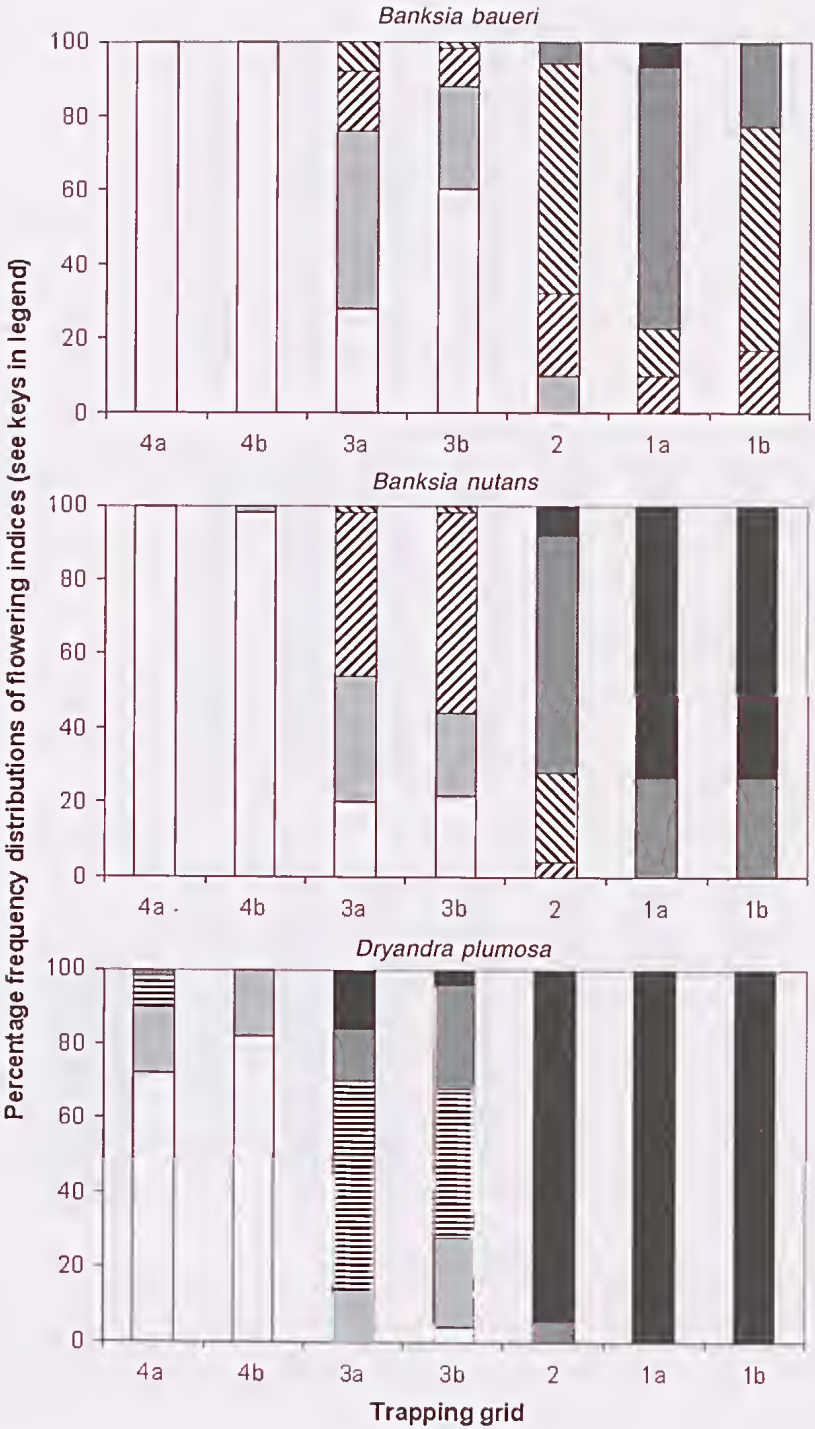


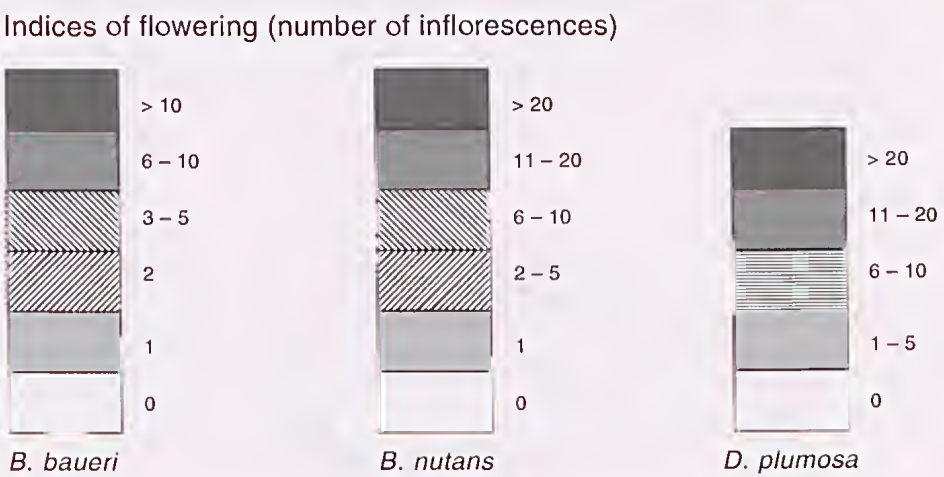
Figure 2. The percentage frequency distributions of plant heights (see key above) for three potential Honey Possum foodplants, *Banksia baueri* (top), *B. nutans* (centre) and *Dryandra plumosa* (bottom). Data were collected in March 2003, at which time the vegetation at Grids 4a and 4b was about five years old, at Grids 3a and 3b it was about 13 years old, at Grid 2 it was about 23 years old and at Grids 1a and 1b it was at least 50 years old.

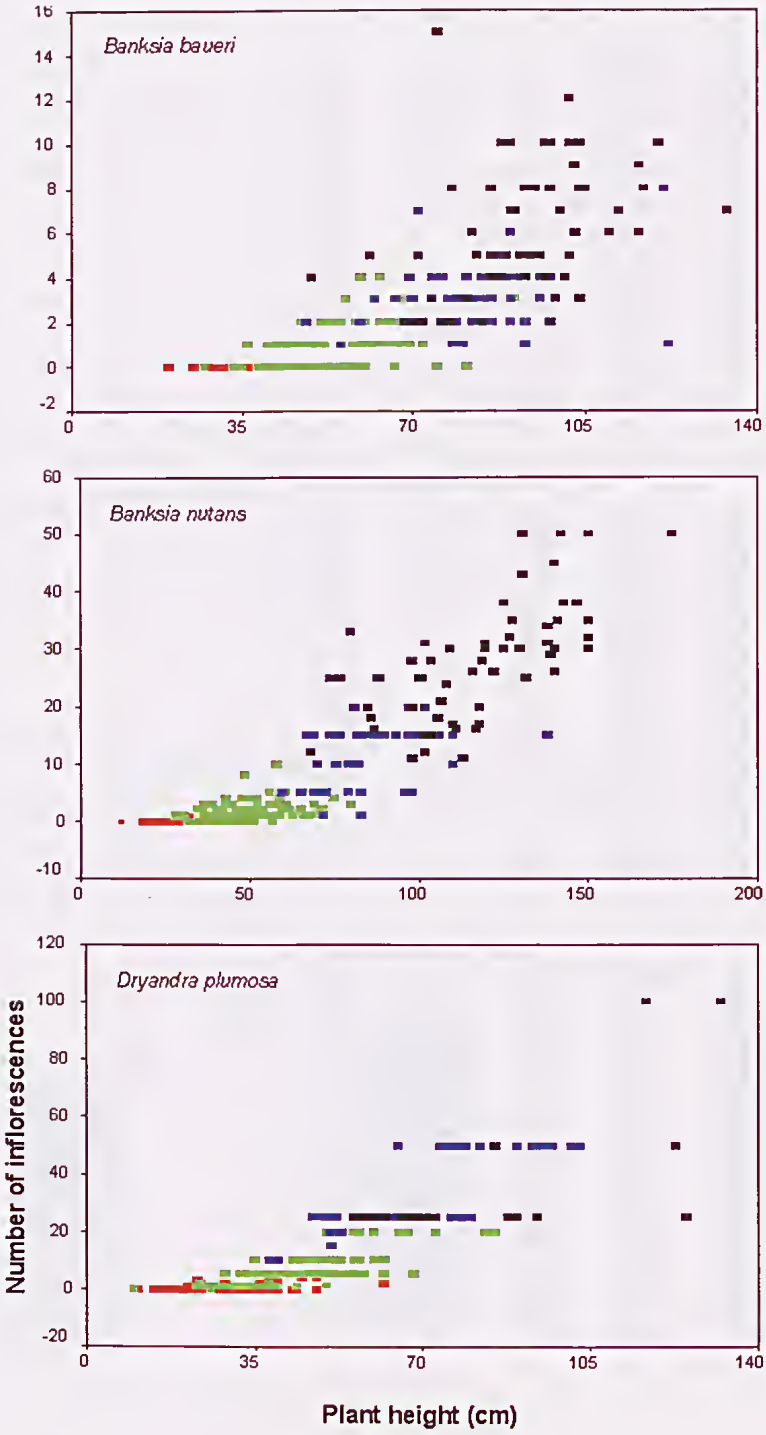

Banksia baueri
Banksia nutans
Dryandra plumosa
Percentage frequency distributions of flowering indices (see keys in legend)
100
80
60
40
20
0
4a
4b
3a
3b
2
1a
1b
Trapping grid

B. nutans and *Dryandra plumosa* plants sampled. At Area 4, most recently burnt in May 1998, none of the *B. baueri* plants sampled in March 2003 showed any evidence of flowering (Figure 3), even though the first post-fire record of flowering by *B. baueri* at this area was in July 2002 (Everaardt 2003). Of the *B. baueri* plants sampled at Area 3, most (95 %) had less than three inflorescences, and many (44 %) had still not flowered (Figure 3). In contrast, all *B. baueri* plants at Area 2 had at least one inflorescence, and many (68 %) had three or more (Figure 3). At Area 1, all had at least two inflorescences and most (87 %) had more than three (Figure 3).

Of the *B. nutans* plants sampled at Area 4, only 1 % showed any evidence of flowering (Figure 3). It is worth noting, however, that another eight plants within the boundaries of Grids 4a and 4b had shown evidence of flowering since the fire in 1998. The first post-fire record of flowering was in January 2002, when only a single, small, inflorescence was recorded on each of the plants involved, all of which were less than 40 cm in height (Everaardt 2003). Of the *B. nutans* plants sampled at Area 3, most (98 %) had less than six inflorescences and some (21 %) had never flowered (Figure 3). In contrast, all of the *B. nutans* plants sampled at Area 1, and

◀ **Figure 3.** The percentage frequency distributions of the indices of flowering (see keys below) for three potential honey possum foodplants, *Banksia baueri* (top), *B. nutans* (centre) and *Dryandra plumosa* (bottom). The flowering index was the number of developing, fresh and old inflorescences on each plant sampled. A zero count indicates that no evidence of flowering was observed on a plant. Data were collected in March 2003, at which time the vegetation at Grids 4a and 4b was about five years old, at Grids 3a and 3b it was about 13 years old, at Grid 2 it was about 23 years old and at Grids 1a and 1b it was at least 50 years old.




Banksia baueri
Banksia nutans
Dryandra plumosa
Number of inflorescences
Plant height (cm)

many (72 %) of the plants at Area 2, had more than ten inflorescences each. Moreover, 73 % of the plants sampled at Area 1 had more than 20 inflorescences (Figure 3).

Figure 3 also shows the flowering index for *D. plumosa*, a species that can regenerate from both lignotuber and seed. As for both *B. baueri* and *B. nutans* plants sampled at Area 4, most (77 %) of the *D. plumosa* plants sampled at this area had yet to show any evidence of flowering, and 95 % of plants had less than six flowers (Figure 3). In comparison, 79 % of the *D. plumosa* plants sampled at Area 3 each had six or more flowers, and only 2 % of plants had yet to flower (Figure 3). Although only 23 plants were sampled at Area 1, all had more than 20 flowers each. A similarly high value was recorded at Area 2, where most (94 %) of the *D. plumosa* plants sampled had more than 20 flowers each, and the rest had 11–20 flowers each (Figure 3).

Figure 4 shows the height of a plant in relation to the number of inflorescences it carried, a significant relationship for *B. baueri* ($r_{308} = +0.793$, $p < 0.001$) and *B. nutans* ($r_{308} = +0.902$, $p < 0.001$), as well as for *D. plumosa* ($r_{271} = +0.865$, $p < 0.001$). These relationships clearly indicate that despite substantial variation between plants in an area, those areas unburnt for longer had taller plants bearing more inflorescences (Figure 4).

DISCUSSION

The response patterns of small mammals after fire are closely tied to their food, shelter and breeding requirements (Friend 1993). One of the greatest impacts of fire on the Honey Possum would appear to be the removal of those foodplants upon which they depend for their survival. Many of these foodplants are slow growing and have a substantial time period, often exceeding five years, before they start flowering again after fire (Wooller *et al.* 2002). Thus, although those foodplants that regenerate only from seed are quick to establish seedlings in the aftermath of fire, these seedlings provide little habitat value or food (flowers) for Honey Possums.

The three foodplants selected for study, *Banksia baueri*, *B. nutans*

◀ **Figure 4.** The height of each *Banksia baueri* (top), *B. nutans* (centre) and *Dryandra plumosa* (bottom) plant sampled in relation to the number of inflorescences on that plant. Each coloured square represents one plant and the number of inflorescences includes developing, fresh and old inflorescences. Data were collected in March 2003, at which time the vegetation at Area 4 was about five years old, at Area 3 it was about 13 years old, at Area 2 it was about 23 years old and at Area 1 it was at least 50 years old.

and *Dryandra plumosa*, were those visited frequently by Honey Possums (Everaardt 2003). It appears likely that Honey Possums, in this area, depend upon specific seasonal foodplants, in particular *B. baueri* and *B. nutans*. Their foodplant preferences changed little despite spatial differences in availability, and it appears that they will travel some distance to satisfy these preferences (Everaardt 2003). Unlike the two banksia species, use of *D. plumosa* was not highly seasonal, but the frequency with which its pollen was carried by Honey Possums seemed to suggest that it was an important foodplant during most seasons (Everaardt 2003, Saffer 1998).

All three species of foodplants were recorded at all four areas, last burnt some 5, 13, 23 and > 50 years earlier. As expected, the height of foodplants increased with time since the vegetation was last burnt. In the most recently burnt area, however, the plants were young and the two banksia species were devoid of any flowers for the first four years. Not surprisingly, some of the *D. plumosa* plants, which can regenerate from lignotuber as well as from seed, flowered within a few years of the fire. The first post-fire flowering by *B. baueri*, after the May 1998 fire, was in July 2002, more than four years since the fire. However, the number of plants that flowered was so low compared to the number of seedlings within the area, that none of the 100 plants measured at this area had yet flowered. A similar interval to first post-fire flowering was recorded in *B. nutans*, with the first inflorescences recorded almost four years after the fire, all of them very small. So few *B. nutans* inflorescences were recorded that just 1 % of *B. nutans* plants measured had an inflorescence. Wooller *et al.* (2002) recorded similar intervals to time of first flowering in *B. baueri* and *B. nutans* for the same heathland after an earlier fire.

For the two obligate re-seeders, *B. baueri* and *B. nutans*, it was 13 years before more than half of the plants had flowered, and 23 years before all plants had flowered. The time to first flowering for the re-sprouting *D. plumosa* was more rapid. Within five years of fire, 23 % of plants had flowered and nearly all (98 %) had flowered within 13 years. The general trend, however, for each of the species of foodplants was that, despite the substantial variation reported within a species at an area, those areas unburnt for longer had taller plants bearing more inflorescences.

Although the nature of the data collected in this examination of foodplants precluded any detailed statistical analyses being performed, the increasing abundance of Honey Possums with increasing time since last fire, and maximal captures of Honey Possums in areas unburnt for some 30 years, corresponds

well to the availability of their foodplants. At one burnt area, there were few flowering foodplants for at least 4–5 years after the fire, more plants had flowered at an area burnt some 12 years earlier, and by 22 years following fire most of their foodplants had flowered (Everaardt 2003).

Other studies undertaken on the impact of fire upon the Honey Possum in the Fitzgerald River National Park showed that there were four factors that significantly (statistically) affected the rates of capture of Honey Possums in this Park. These factors were: (i) the time elapsed since the vegetation was last burnt, (ii) annual rainfall in the preceding year, but not the current year, (iii) the season of the year, and (iiii) the trapping grid (Wooller *et al.* in prep., Everaardt 2003).

The availability of both obligate re-seeders and re-sprouters within the heathland vegetation of the Fitzgerald River National Park would seem to be of value to this flower-feeding specialist. Whilst it appears that Honey Possums prefer many foodplants that do not flower for many years following fire, the availability of plants such as *Dryandra plumosa*, *Calothamnus gracilis* and *Eucalytpus buprestium*, capable of flowering within a few years after fire, may provide the sustenance that they require as they search for their preferred foodplants which only flower in areas longer unburnt.

ACKNOWLEDGEMENTS

The study reported in the present paper formed part of my PhD research on the impact of fire on the Honey Possum in the Fitzgerald River National Park. The completion of this research would not have been possible without the generous support and assistance provided by the following people. From Murdoch University, I would like to thank my supervisor, Associate Professor Ron Wooller, and co-supervisor Professor Stuart Bradley. Personal funding was provided from an Australian Postgraduate Award stipend and a Murdoch University Completion Scholarship.

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BIODIVERSITY ATTRIBUTES OF AN ISOLATED WOODLAND FRAGMENT IN METROPOLITAN PERTH, WESTERN AUSTRALIA

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ABSTRACT

The macroscopic biological diversity of a small (<1ha), isolated bushland remnant at the edge of suburban Perth comprises over 130 species. Most taxa are invertebrates or vascular plants, whereas terrestrial vertebrates make a minor contribution to species richness. Intensive survey of this small fragment ensured that the flora and fauna were satisfactorily described, however, additional species are certain to exist and would be recorded by further scrutiny. The conservation 'value' of remnants is such that all areas of bushland remaining on the Swan Coastal Plain should be protected to preserve biodiversity values. It is suggested that biological survey procedures as currently practiced in the state of Western Australia do not adequately document biological diversity.

INTRODUCTION

The south-west of Western Australia is a global biodiversity 'hotspot' (Myers *et al.* 2000), to which the Swan Coastal Plain makes a major contribution. Although the term biological diversity, or its shortened form 'biodiversity', is frequently used as a descriptor for a range of situations, it is seldom clearly defined. The simplest and therefore most widely-used measure of biodiversity is species richness: the number of individual taxa occupying a specified area. Clearly, in general and on average, the larger an area, the greater will be its diversity (Arrhenius 1921; MacArthur and Wilson 1963).

As a consequence of the species-area relationship, it is especially difficult to fully document the biodiversity of large survey areas. Although the cumulative number of species recorded will be greater, many species will remain undetected due to their low density (particularly rare

species), secretive habits, inactivity (seasonal or diurnal), or senescence. The longer and more detailed a survey, the greater the variety of sampling methods, and the finer the resolution of fauna habitats or vegetation communities recognised, the more representative it will be in terms of characterising the biota of a study area, and therefore a region, or a biological zone (see Elton (1946), for a discussion of the validity of survey data). Two principal components, intensity and duration, will ultimately determine the comprehensiveness of a survey. The experience of the observers and their familiarity with the biota of the region will also influence survey outcomes.

Fragmentation and ultimately isolation of bushland areas in urban and agricultural settings is of widespread occurrence in southern and eastern Australia (Breckwoldt 1986). Loss of habitat has a negative influence on biodiversity, i.e. the number of animals and plants in an area will decrease over time (e.g. Commonwealth of Australia 1995; Jellinek *et al.* 2004; Bennett 1990 and references therein; Grimbacher *et al.* 2006). The precise alterations to species diversity and composition will depend on the history and nature of environmental modification. The biodiversity reduction response will be acute for areas that are heavily damaged, particularly where land-forming removes all vegetation, and only moderate for areas on the urban fringe, in which condition gradually deteriorates over time as a result of weed infestation and anthropogenic use and incursion. There are a variety of causes (e.g. introduced predators, fire, drought) for localised extinction. However, any factor that reduces population size will have a greater potential to affect long-term viability and ultimately extirpation due to stochastic (chance) fluctuations or accidental loss if the population is small and isolated. Urban environments are a major environmental concern because entire landscapes are completely destroyed or otherwise irretrievably altered when incorporated into an urban framework (see Garden *et al.*, 2006).

The urban arc of the expanding Perth megalopolis extends from the seaward fringe of the northern suburbs, north and south of the river, past Mandurah and down to Bunbury. With the exception of localised areas near Pinjarra and Yanchep, almost the entirety of the Swan Coastal Plain has been cleared for urban, suburban and peripheral expansion. A series of studies have examined the landscapes (e.g. Semeniuk 1988; Semeniuk and Glassford 1989; Seddon 1972 and references therein), components of vertebrate fauna (Cooper 1995; Davidge 1979; How and Dell 1990; Maryan 1984; Maryan *et al.* 2002; Mawson and Massam 1995;

Recher and Serventy 1991; Turpin 1990, 1991), vegetation (Beard 1979) and floristics (Cresswell and Bridgewater 1985; Keighery and Keighery 1993; Gibson *et al.* 1994) including weeds (Keighery 1998) of bushland on the Swan Coastal Plain near Perth. There is also an ever increasing quantity of unpublished material on urban bushland remnants, and a range of information, of variable quality, in consultant reports. Much of this information has been summarised in short form in the BushPlan (Department of Environmental Protection 1998) and subsequent Bush Forever documents (Government of Western Australia 2000). These studies show that while native mammals are highly susceptible to localised extinction in urban remnants, components, at least, of various animal groups may persist. Floristic diversity may also remain high, and remnants may support rare plant species and communities (Kirkpatrick 1986; Gibson *et al.* 2000). This paper reports on the biota of an isolated patch of *Banksia*-dominated woodland in southern metropolitan Perth, and provides an example of the importance of remnants for preserving biodiversity in the face of habitat loss due to continued urban development.

METHODS

Cocos Reserve (32°06'33"S 115°49'18"E) is situated in the suburb of Bibra Lake, City of Cockburn. It is less than one hectare in size, and is sandwiched between extensive cleared areas on all sides; to the south by a sandy track and railway, to the north by a large expanse of bare sand, and to the east by a wide sandy area adjacent to a major road. The area lies on siliceous white-grey Bassendean sands and there is only minor soil (humic) development. There is low to moderate leaf-litter accumulation, particularly around the dominant trees that form the overstorey; *Eucalyptus marginata*, *Allocasuarina fraseriana* and *Banksia attenuata*. The midstorey is moderately well developed and the site had remained unburnt for several years. Principal weeds are scattered Geranium *Pelargonium capitatum* and Veldt Grass *Ehrharta calycina* along edges.

Assessment of the flora and fauna was made by trapping and observation. Throughout January and into the first half of February 2003, pit-trapping was undertaken on most nights with four large buckets (30cm deep) with a 4m drift fence, and five small plastic containers (10cm deep). The number and types of animals captured were noted for each trap on each day. Elliott traps were tried initially but produced only the House Mouse *Mus musculus*. I recorded birds by aural and visual means; the species and the number of individuals were noted on each occasion. Botanical survey was carried out twice intensively and

also incidentally during and after trapping visits. A species recognition, or 'morphospecies' approach was used to classify the majority of invertebrate taxa.

RESULTS

A rich community of animal and plant species was recorded from Cocos Reserve (Table 1). The major contribution to faunal diversity was from the invertebrate community, including at least 70 species from 14 taxonomic groups (Table 1). This is not a complete list as new species of invertebrates were recorded on each trapping day. Many of the insects, spiders and acarines were abundant at the site.

Vertebrate animals included a single species of frog, several reptiles, predominantly skinks, and a small but apparently viable group of sedentary and roaming birds (Table 1, Appendix 1). Seven additional bird species were observed passing over the site; these waterbirds were not included as they are exclusive to habitats at nearby Little Rush

Table 1. Biodiversity attributes table for Cocos Reserve.

Taxon	Richness	Comments
Lizards (Reptilia: Squamata)	5 species	predominantly skinks
Frogs (Amphibia: Anura)	1 species	moving between wetlands ?
Birds (Aves) – native taxa	13 species	some resident individuals additional birds pass over
Spiders (Arachnida: Araneae)	15+ species	
Mites (Arachnida: Acarina)	2 species	small ground-dwelling species
Scorpions (Arachnida: Scorpiones)	1 species	
Beetles (Insecta: Coleoptera)	8 species	
Grasshoppers and crickets (Insecta: Orthoptera)	8 species	
Bees, ants and wasps (Insecta: Hymenoptera)	20+ species	over half the species are ants
Termites (Insecta: Isoptera)	2 species	observed not trapped
Bugs (Insecta: Hemiptera)	6 species	includes two cicada species
Cockroaches (Insecta: Blattodea)	2 species	
Flies (Insecta: Diptera)	3 species	including House Fly
Silverfish (Insecta: Thysanura)	2 species	
Earwigs (Insecta: Dermaptera)	1 species	
Mantids (Insecta: Mantodea)	1 species	
Centipedes (Myriapoda: Chilopoda)	2 species	both species trapped
Slaters (Crustacea: Isopoda)	1 species	? introduced species
Monocotyledons (Liliopsida) – native taxa	18 species	additional sedges present
Dicotyledons (Magnoliopsida) – native taxa	32 species	mistletoe present ?

Lake and other Beeliar wetlands. No nocturnal birds were observed, and the only mammals were non-native species (Appendix 1).

To date 50 species of native vascular plants have been identified at the site (Table 1, Appendix 2) and others were recorded. Strata components include six trees, 17 varieties of shrubs, and the majority of the plant diversity in the understorey layer, particularly amongst the herbs and sedges (Appendix 2). More than 16 exotic (introduced) plant species occur – mainly herbs and grasses; additional species would flourish in winter.

DISCUSSION

The persistence of a diverse community of animal and plant species at Cocos Reserve is exceptional given the small size of the reserve (< 1 ha), particularly as the site is completely isolated from adjacent bushland. The major contribution to biodiversity (~80% of fauna taxa) is due to the invertebrate community. Harvey *et al.* (1997) also documented a rich assemblage of invertebrates at urban bushland remnants near Perth, including many spiders and Baeine wasps. That the majority of diversity is amongst the invertebrates is not unexpected, because globally there are vastly more invertebrates than vertebrates (Barnes, 1980; Wilson, 1987). This suggests that in order to fully evaluate the biodiversity of a study area, survey objectives should include assessment of invertebrates. We can only begin estimating the relative value of diversity if we enhance the ecological information that is obtained.

Plants and animals (particularly vertebrates) are the most familiar types of organisms and the easiest to identify accurately, hence the level of expertise and state of knowledge is far superior to that for other groups. They are consequently the focus of the majority of biological surveys; our principle source of data for estimating biodiversity. They are assessed in preference to micro-organisms, fungi, invertebrate animals, or non-vascular plants. The vertebrate fauna and vascular plants of the Swan Coastal Plain and vicinity have been capably described and annotated (e.g. How 1998; Storr and Johnstone 1988; Marchant *et al.* 1987), and in some cases, analysed (How and Dell 1994, 2000). Although there have been some surveys of terrestrial environments that have examined specific invertebrate groups (e.g. Andersen 1986; Rossbach and Majer 1983; Gwynne *et al.* 1988), comprehensive surveys of invertebrate diversity are rare.

Vertebrates are used as the main faunal indicators of environmental health for environmental impact assessment, but it is frequently the absence of rare species, rather than the presence of a diverse community, that tips the balance in favour of

development. The comparative 'value' of bushland remnants is therefore determined on the basis of few taxonomic groups, and may in some cases be strongly, and somewhat subjectively influenced by the existence of populations of a single species. Reduced vertebrate diversity (particularly of prominent taxa such as mammals) in remnants due to isolation may not correspond to overall faunal diversity. Indeed, if we extrapolate biodiversity attributes of the better known faunal groups to the invertebrates, we would anticipate that many species of insects and arachnids are likely to be restricted to the Swan Coastal Plain and, by extension, to specific habitats within the landscape mosaic. If any legitimate attempts are to be made to retain biodiversity, then we have an obligation to examine other components of the biota in greater detail, refine methods of investigation and analysis to establish criteria and guidelines for preservation of biodiversity values, determine the full range of taxa that exist, and investigate ecological relationships more thoroughly.

Considering the small size of the Cocos Reserve remnant, it supports a diverse array of plant taxa. Over 50 native species have been recorded and more are likely to occur, particularly additional sedges, low shrubs, herbs (including orchids), mistletoes and weeds. Species-area curve extrapolations for plants based on the number of species recorded at Cocos Reserve and using data for several other comprehensively surveyed but relatively homogeneous sites on the Swan Coastal Plain (Shenton Park bushland and Talbot Road bushland), indicates an approximate relationship of the form $S = 45A^{0.415}$ where S is plant species richness and A is area in hectares. Sites such as the Brixton Street wetlands (Keighery and Keighery 1993) with multiple habitats and a complex array of understorey species, greatly exceed this average expectation based on area alone. This index is more appropriate for surveys of a single vegetation type such as *Banksia* woodland or Eucalypt forest, but requires comprehensive, detailed floristic information to be a useful and potentially meaningful measure. Flora surveys often focus on vegetation communities rather than floristic composition *per se* (although composition may be used to delineate communities), and assessment of representation is usually made on this basis, as is the case for the Perth region (Government of Western Australia 2000). The analysis presented here, although highly simplistic in its current form, suggests an alternative or complementary method for evaluating sites that is specifically relevant to interpretations based on biodiversity.

Limitations of the current survey are primarily in relation to duration, in that the data for

fauna were collected over a five week period (longer than most fauna assessment surveys), and in timing, because although summer is an appropriate time to survey reptiles (How 1998) and many insects, it may be less suitable for other fauna. Most floristic work was carried out in summer, so while the list is comprehensive for that season, it is possible that plants without remnant dry season structures could have been missed. Additional fauna species would be recorded during trapping in other seasons, and certain species are not amenable to capture by trapping, hence further opportunistic searches would contribute to a more comprehensive evaluation. The comparatively small size of the study area facilitated complete bird surveys on each occasion based on observation and call identification, but migrant or nomadic species may use the area in other seasons. The reptile list is likely to be adequate but incomplete because species accumulation through trapping may take many years (How 1998). Familial composition is however similar to other herpetofaunal surveys (e.g. Davidge 1979; How and Dell 1994; Maryan *et al.* 2002) in that the majority of species were skinks. The presence of the Moaning Frog *Heleioporus eyrei* in summer was unusual as there was no rain at the time. Other frog species may move through the area from local wetlands during the winter months, although they would have to traverse areas of bare soil with no shelter. Invertebrates appeared to be relatively active at the time of trapping, but I am not aware of any studies that give a clear indication of the most appropriate time (or times) to collect invertebrates in the south-west of Western Australia.

Bushland remnants often support a range of fauna species (How and Dell 1994; Kitchener and How 1982; this study) and vegetation communities (e.g. Keighery and Keighery 1993), and have value as habitat (Hodgson *et al.* 2006) even when of small size (Jellinek *et al.* 2004). However, in urban areas these sites are so sparsely distributed that effective and comprehensive retention of all biological attributes is no longer a feasible objective. The emphasis must instead be placed on the retention and persistence of as great a variety of ecosystem components as possible. Given the rapid rate of attrition of bushland in the Perth region, the only reasonable conclusion seems to be, that in order to maintain biodiversity (including all its components), *any* remaining areas of bushland in urban and suburban areas must be retained, and areas on the expanding fringe should be protected from degradation and loss. Proposals to delete portions of the landscape and their biological components need to be examined very closely, particularly, strategically and

specifically in areas of urban expansion where so few examples of diverse bushland remain, and in a region where there are numerous endemic taxa (Hopper 1979; Keighery 1996; Beard *et al.* 2000). The choices that are made now will determine the future of biodiversity in the region.

In order to fully appreciate the biodiversity attributes of a bushland area, we need to take a fine-scale local viewpoint, but a regional perspective. These two aspects are not always compatible, and it is not until the level of knowledge becomes adequate that rational decisions can be made about biodiversity conservation within the context of representative reservation. The Swan Coastal Plain is a special case in that it is the focus of urban expansion, but it has also been the focus of detailed biological study. However, even in this instance where there is an acceptable level of understanding of biodiversity components, there is an inadequate basis for approaching bushland conservation that is specifically relevant to biotic significance. In order for a rational system to be designed that has sufficient cohesion to ensure that it is culturally and politically persuasive, there is a requirement for a strategic and systematic approach that has explicit goals. This system must have the capability to incorporate the findings of biological surveys and utilise the information obtained to inform relevant and reasonable management decisions, including selection and allocation of areas with the sole objective of nature conservation.

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APPENDIX 1

Vertebrate fauna recorded at Cocos Reserve bushland remnant.
* denotes introduced species. Ground fauna: l = large pit-fall, s = small pit-fall, e = Elliott trap, o = observation. Birds: r = resident, v = local visitor, s = seasonal visitor, B = breeding, percent of visits recorded in brackets.

Amphibians			
Heleioporus eyrei	l		
Reptiles			
Cryptoblepharus buchananii	lso		
Ctenotus fallens	o		
Lerista elegans	l		
Lerista lineata	ls		
Menetia 'greyii'	lo		
Birds			
*Laughing Turtle-Dove *Streptopelia senegalensis*		v	(25%)
Rainbow Bee-eater *Merops ornatus*		s(r)	(50%)
Splendid Fairy-wren *Malurus splendens*		v?	(8%)
Western Gerygone *Gerygone fusca*		r	(100%)
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*		r	(100%)
Red Wattlebird *Anthochaera carunculata*		v	(25%)
Singing Honeyeater *Lichenostomus virescens*		rv	(58%)
Brown Honeyeater *Lichmera indistincta*		rv	(92%)
Rufous Whistler *Pachycephala rufiventris* (male)		r	(42%)
Willie Wagtail *Rhipidura leucophrys*		v	(8%)
Grey Fantail *Rhipidura fuliginosa*		rB	(92%)
Black-faced Cuckoo-shrike *Coracina novaehollandiae*		v	(8%)
Australian Raven *Corvus coronoides*		v	(67%)
Silvereye *Zosterops lateralis*		v	(58%)
Mammals			
*House Mouse *Mus musculus*	e		
*Rabbit *Oryctolagus cuniculus*	o		

APPENDIX 2

Vascular plants recorded at Cocos Reserve bushland remnant. The list excludes plantings (8 species). Plants are listed alphabetically within life-form groupings.

Trees

Allocasuarina fraseriana
Banksia attenuata
Banksia ilicifolia
Banksia menziesii
Eucalyptus marginata
Eucalyptus gomphocephala

Shrubs

Acacia cochlearis
Acacia rostellifera
Acacia sp.
Astroloma sp.
Bossiaea eriocarpa
Daviesia divaricata
Daviesia nudiflora ?subsp.
Gompholobium capitatum
Hakea prostrata
Hibbertia huegelii
Hibbertia hypericoides
Hibbertia racemosa
Hypocalymma robustum
Leucopogon sp.
Petrophile linearis
Petrophile macrostachya
Xanthorrhoea preissii

Herbs and Forbs

Burchardia umbellata
Carpobrotus sp.
Cassytha sp.
Conostylis aculeata
Crassula sp. 1
Crassula sp. 2
Dasypogon bromeliifolius
Dianella revoluta var. *divaricata*
Drosera ?glanduligera
Laxmannia squarrosa
Lomandra sp. 1
Lomandra sp. 2
?Microtis sp.
Patersonia occidentalis
Phlebocarya ciliata
Ptilotus drummondii
Scaevola canescens
Scaevola repens
Thysanotus manglesianus/patersonii complex
Thysanotus sparteus

Climbers

Hardenbergia comptoniana
Kennedia prostrata

Rushes and Sedges

Desmocladus flexuosa
Lepidosperma longitudinale
Mesomelaena sp.
Schoenus curvifolius
Schoenus grandiflorus

Introduced Flora

Anagallis arvensis var. *caerulea*
Arctotheca calendula
Brassicaceae sp.
Briza maxima
Briza minor
Ehrharta calycina
Euphorbia peplus
Euphorbiaceae sp.
Gladiolus caryophyllaceus
Hypochaeris glabra
Pelargonium capitatum
Poaceae sp.
Romulea rosea
Solanum nigrum
Ursinia anthemoides
Wahlenbergia capensis

THE DONNELLY RIVER CATCHMENT: AN IMPORTANT REFUGE FOR ALL OF SOUTH-WESTERN AUSTRALIA'S ENDEMIC FRESHWATER FISHES AND THE POUCHED LAMPREY (*GEOTRIA AUSTRALIS*)

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ABSTRACT

The fish fauna of the Donnelly River is described from historical published and unpublished data and from captures during 2006. The Donnelly River catchment is one of only two river systems that contain all of south-western Australia's eight endemic freshwater fish species. The high diversity of fishes in the Donnelly River catchment, including Lake Jasper, Lake Wilson and Lake Smith, is likely to be due to the heterogeneity of aquatic habitats in the system. For example, species such as the Salamanderfish and Black-stripe Minnow are restricted to ephemeral pools and floodplain environments on Scott Rd and around Lake Smith. Lake Smith is also the only known location within the catchment of the rare Balston's Pygmy Perch and, together with Lake Wilson, is the only known habitat in the catchment of the large Freshwater Cobbler. The Western Minnow, Western Pygmy Perch and Nightfish were relatively common and widespread through the catchment; occurring in most habitat types. The rare Western Mud Minnow is restricted to headwater streams and is very uncommon in the system, in part possibly due to predation by exotic species. It is also one of the few systems that provide extensive habitats for the adult and larval stages of the Pouched Lamprey. Three introduced fishes are known from the Donnelly River, the Eastern Mosquitofish, Redfin Perch and Rainbow Trout, the latter being the most widespread; presumably as a consequence of the long term stocking of the species into the catchment. Despite the presence of these introduced species, the Donnelly River should be considered of high conservation importance due to its south-western endemic fish populations.

INTRODUCTION

The freshwater fish assemblage of the south-west of Western Australia (otherwise known as the Southwest Coast Drainage Division) has the highest proportion (80%) of endemic fishes in the country (Morgan *et al.* 1998). Of the 10 native freshwater fishes that are naturally found within the south-west, eight are found nowhere else.

The catchment of the Donnelly River is comparatively small, covering an area of approximately 1600 km^2, with the headwaters arising ~60 km inland before flowing south-west where it discharges into the Southern Ocean (Hodgkin and Clarke 1989, Figure 1). Situated in the high rainfall belt in the south-western corner of Western Australia, the catchment is largely uncleared (80–90%) (Hodgkin and Clarke 1989, Pen 1999). Although there are ~20 river systems that are larger than the Donnelly River in south-western Australia, it is sixth in terms of mean annual discharge (310000 ML). Within the Donnelly River catchment are the near pristine wetlands of Lake Jasper, Lake Wilson and Lake Smith. Parts of the lower Donnelly River, Barlee Brook and much of Lake Jasper are of important cultural and archaeological significance and many of these sites are Registered Aboriginal Heritage Sites (Dortch and Godfrey 1990, Goode 2003, Goode and Irvine 2006).

The distributions of freshwater fishes inhabiting the Donnelly River and the adjacent lakes were documented by Morgan *et al.* (1998), and include data from the collections in the Western Australian Museum and from those made by Christensen (1982) and from Jaensch (1992) in Lakes Jasper, Wilson and Smith. Hodgkin and Clarke (1989) provided a list of the fish species found within the Donnelly River Estuary and also included information on the catchment characteristics and physical features. Hoddell (2003) examined the phylogeny (i.e. evolutionary relationships) of the Western Hardyhead (*Leptatherina wallacei*) and the Swan River Goby (*Pseudogobius olorum*) in the lower estuary and Lake Jasper and compared these to populations elsewhere in south-western Australia.

Since the mid 1970s, a great deal of research has been conducted into biological aspects of the Pouched Lamprey (*Geotria australis*) with much of the work (almost 100 scientific publications) involving lampreys from the Donnelly River; sites of capture of adults and ammocoetes (larvae) being presented in Morgan *et al.* (1998). The Donnelly River is also regularly stocked with Rainbow Trout (*Oncorhynchus mykiss*) by the Department of Fisheries Western Australia and limited information on their diets are presented in Morgan *et al.* (2004).

By collating relevant information in the above studies and

through additional sampling for fishes in the lower Donnelly River, this study aims to provide an overview of the fishes in the Donnelly River and thus determine its conservation significance in terms of the highly endemic fish fauna of the region.

METHODOLOGY

FISH DISTRIBUTIONS IN THE DONNELLY RIVER

A number of studies provide information regarding specific aspects of the fishes of the Donnelly River. Utilising GPS co-ordinates and species occurrences in Christensen (1982) (11 sites), Jaensch (1992) (three sites), Morgan *et al.* (1998) (24 sites) and Hoddell (2003) (three sites), with additional sampling of five sites during June 2006, we generated a series of species maps using *MapInfo* (MapInfo Corporation 1998) (see Figure 1). Information regarding species in the estuary was collated from Hodgkin and Clarke (1989), Hoddell (2003), Brearley (2005) and from samples obtained during June 2006 (this study).

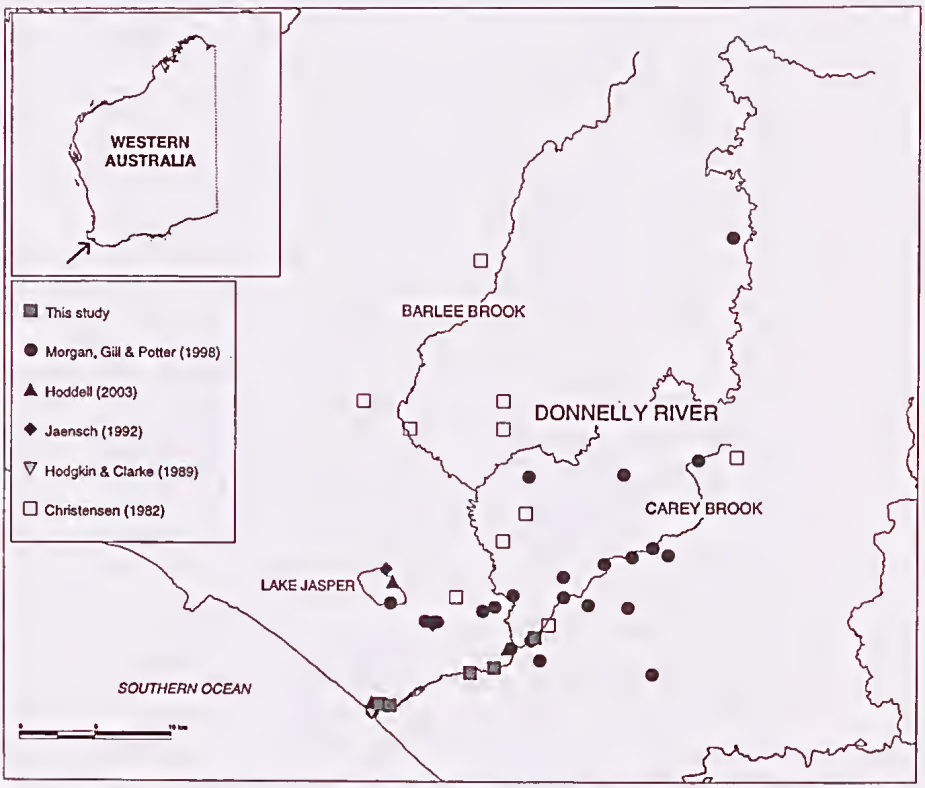

Figure 1. Sites sampled for fish in June 2006 and during relevant past studies; each of which was used to provide species distributions throughout the catchment.

Sampling that was undertaken during June 2006 included four sites within the estuary (tidal influence) and one site on Carey Brook (Figure 1). Sampling methods included monofilament gill nets, fine mesh (3 mm) seine nets, and both boat deployed (240v) and backpack (12v) electrofisher. At the time of sampling the river mouth was open and the river was tidally influenced to at least Boat Landing Road.

RESULTS

In the following synopsis of the fish fauna of the Donnelly River, we have grouped species into a number of conventionally used life history categories, i.e. species have been grouped if they are strictly freshwater, estuarine or whether they are introduced fishes. A further category has been included to account for the anadromous Pouched Lamprey, which belongs to a primitive group of fishes known as the Agnatha.

NATIVE FRESHWATER FISHES

The endemic freshwater fishes that are currently known to occur in the Donnelly River catchment include the Salamanderfish (*Lepidogalaxias salamandroides*), the Freshwater Cobbler (*Tandanus bostocki*), the Western Minnow (*Galaxias occidentalis*), the Black-stripe Minnow (*Galaxiella nigrostriata*), the Western Mud Minnow (*Galaxiella munda*), the Western Pygmy Perch (*Edelia vittata*), Balston's Pygmy Perch (*Nannatherina balstoni*) and the Nightfish (*Bostockia porosa*).

The Salamanderfish is seldom found in the main channel, or even a major tributary, of any river system and the Donnelly is no exception. Within the Donnelly catchment the Salamanderfish has been captured from: the swamps surrounding Lake Smith, in pools along Scott Rd and on a large flat on Pneumonia Rd (Figure 2). Within the Donnelly catchment, the Freshwater Cobbler is only known from Lake Smith and Lake Wilson (Figure 3) (Jaensch 1992, Morgan *et al.* 1998). The Western Minnow is widespread throughout the Donnelly River and is also very abundant in Lakes Jasper, Wilson and Smith (Figure 4). However, the Western Mud Minnow and Black-stripe Minnow were far more restricted; the former being recorded at only three localities by Christensen (1982) (Figure 5), and the latter in a number of pools/floodwaters along Scott Road (Figure 6). The Western Pygmy Perch is widespread and relatively common in a number of habitats throughout the Donnelly River catchment (Figure 7). It is particularly abundant in Lake Smith and Lake Wilson. Balston's Pygmy Perch is extremely rare, and within the Donnelly River catchment is only known from Lake Smith, with one individual found in Fly Brook (Figure 8) (Morgan *et al.* 1998). The

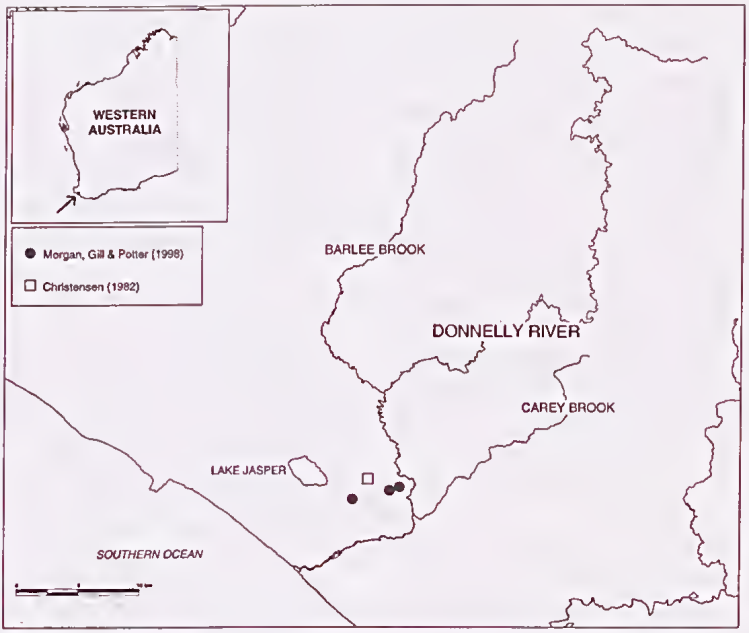

Figure 2. Capture sites of the Salamanderfish within the Donnelly River catchment.

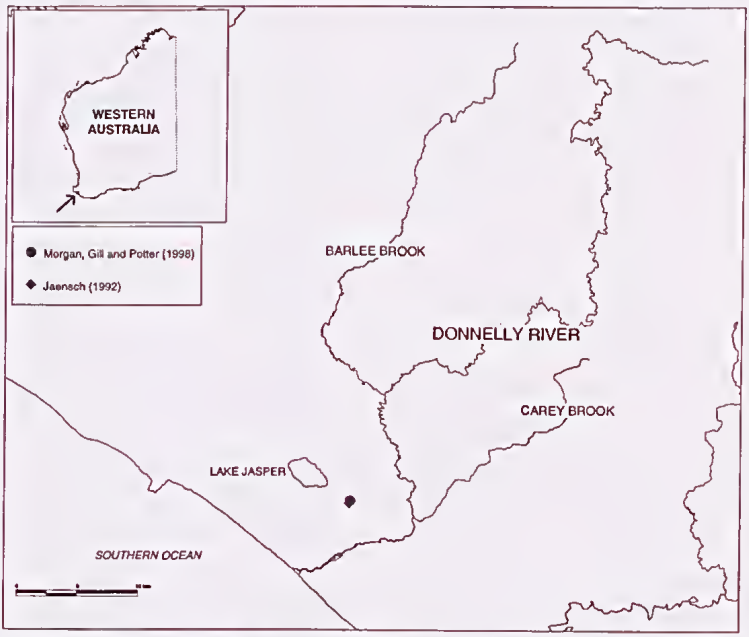

Figure 3. Capture sites of Freshwater Cobbler within the Donnelly River catchment.

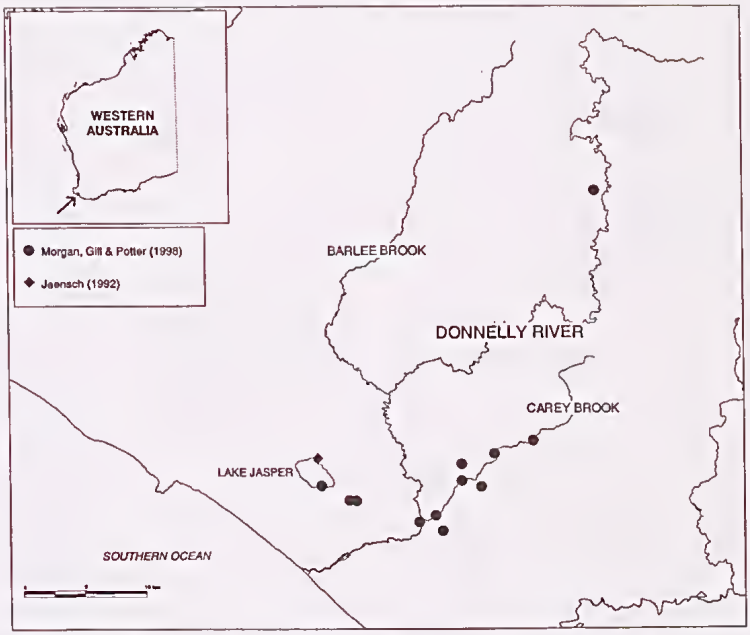

Figure 4. Capture sites of the Western Minnow within the Donnelly River catchment.

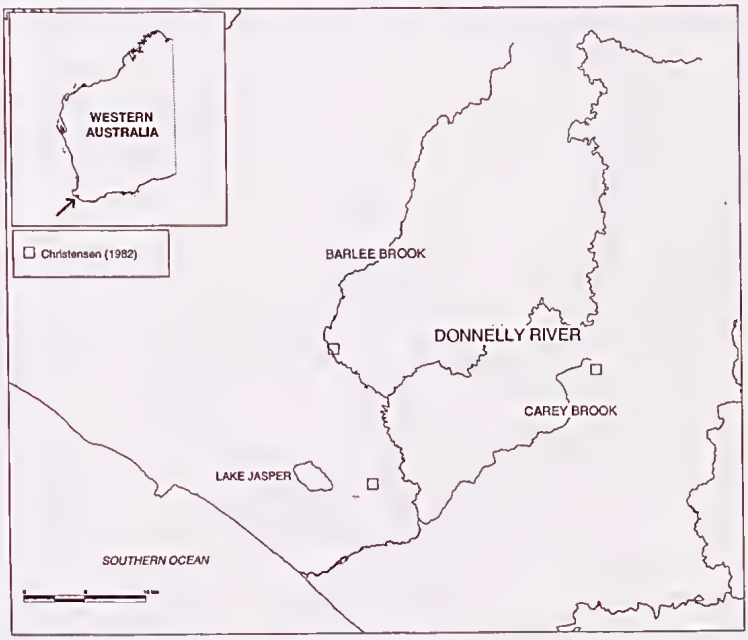

Figure 5. Capture sites of the Western Mud Minnow within the Donnelly River catchment.

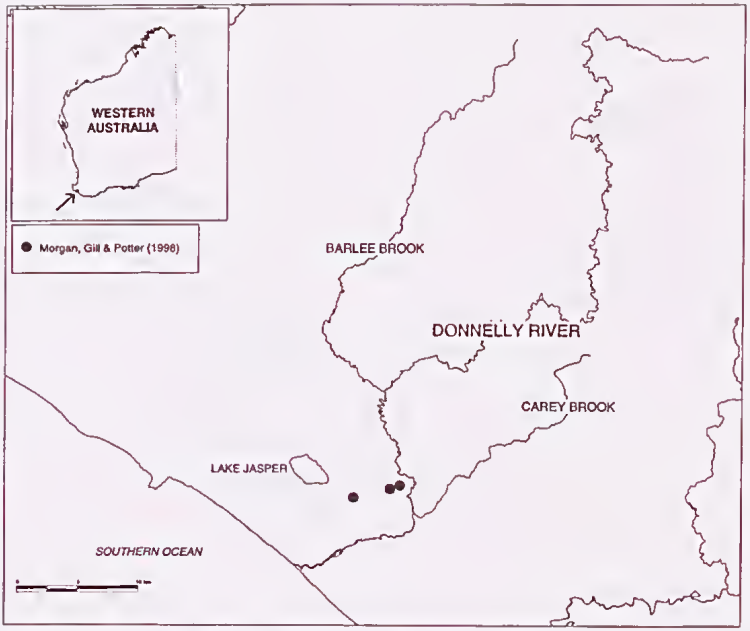

Figure 6. Capture sites of the Black-stripe Minnow within the Donnelly River catchment.

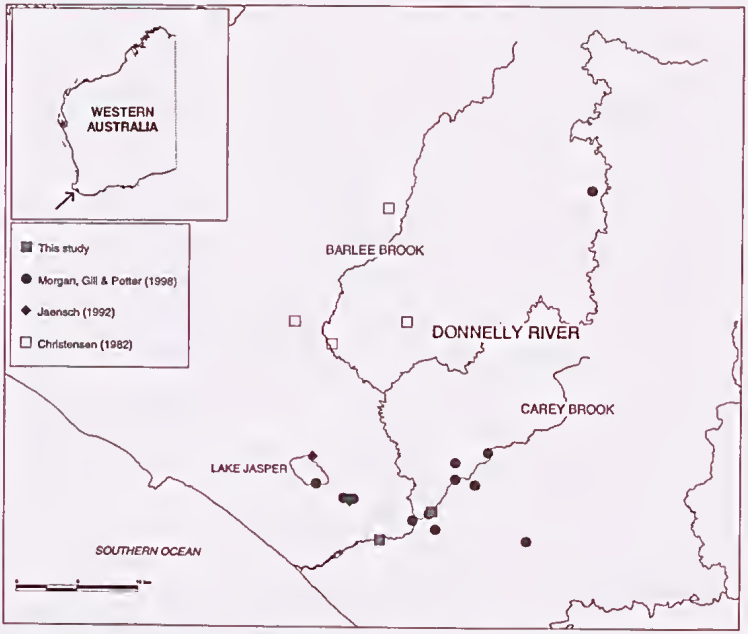

Figure 7. Capture sites of the Western Pygmy Perch within the Donnelly River catchment.

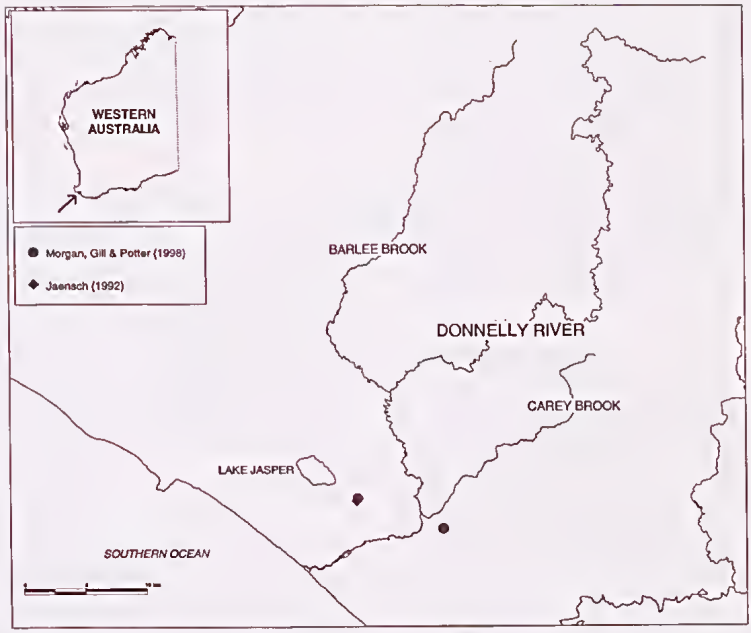

Figure 8. Capture sites of the Balston's Pygmy Perch within the Donnelly River catchment.

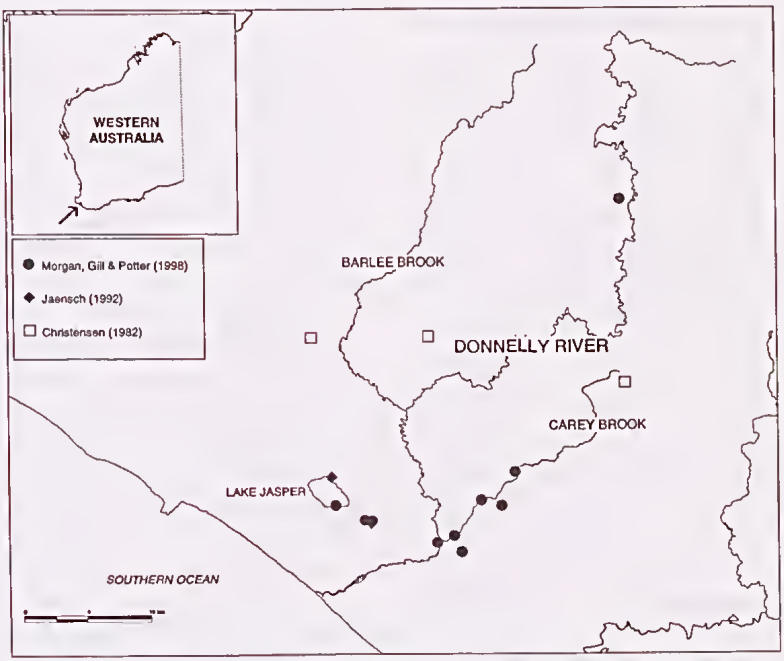

Figure 9. Capture sites of the Nightfish within the Donnelly River catchment.

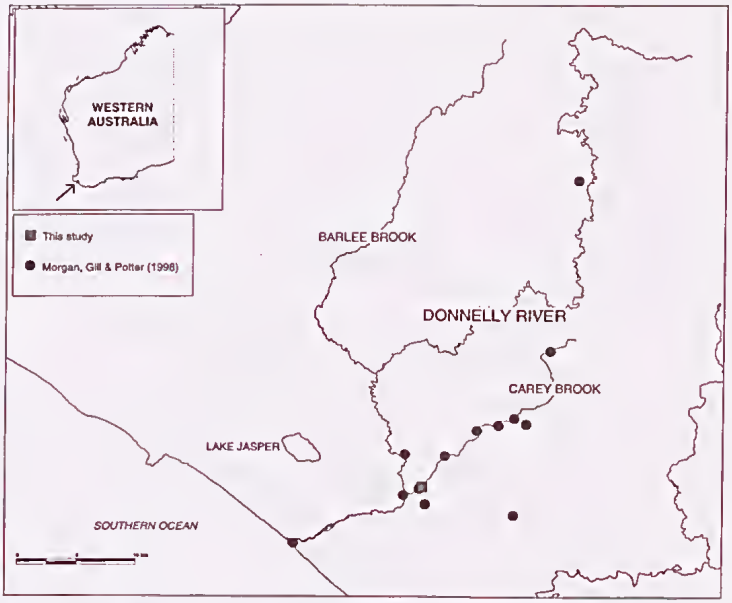

Figure 10. Capture sites of the Pouched Lamprey within the Donnelly River catchment. The site at the mouth and the upper river represents adults caught by colleagues at Murdoch University. Most other sites indicate ammocoete (larval) beds.

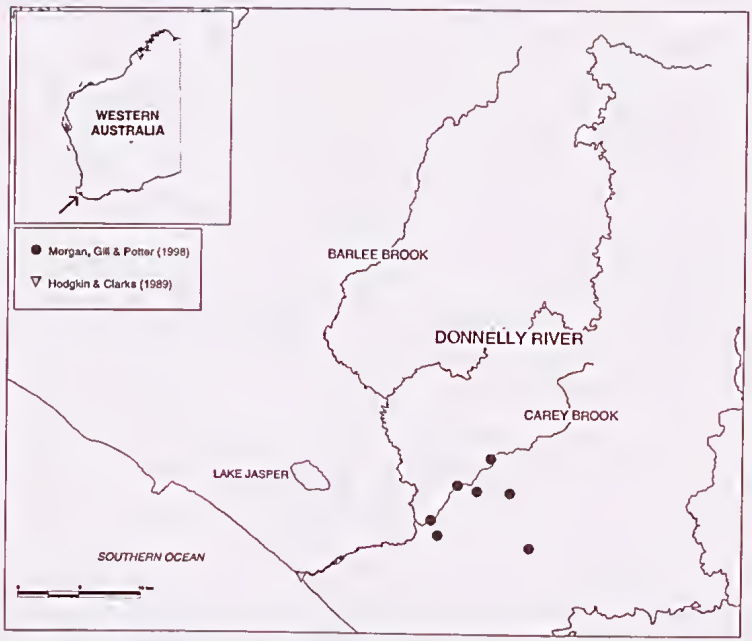

Figure 11. Capture sites of Rainbow Trout within the Donnelly River catchment.

Nightfish is found throughout the catchment including in the Lakes Jasper, Wilson and Smith (Figure 9).

Pouched Lamprey

Pouched Lamprey ammocoetes (i.e., larvae (see discussion for life-cycle)) were found at a number of sites within the Donnelly River (Figure 10). Furthermore, 92 downstream migrant staged Pouched Lampreys were recorded at Carey Brook during this study.

Estuarine Fishes

Our sampling in June 2006 in the estuary captured a number of estuarine species including Black Bream (*Acanthopagrus butcheri*), Tarwhine (*Rhabdosargus sarba*), Australian Herring (*Arripis georgianus*), Sea Mullet (*Mugil cephalus*), Yelloweye Mullet (*Aldrichetta forsteri*), Western Hardyhead (*Leptatherina wallacei*), Swan River Goby (*Pseudogobius olorum*) and South West Goby (*Afurcagobius suppositus*). During recent sampling we also captured the South West Goby in Carey Brook and the Swan River Goby was previously captured a considerable distance up the main channel of the Donnelly River (see Morgan *et al.* 1998). Hodgkin and Clarke (1989) report a number of marine/estuarine fishes from the Donnelly River estuary including: Black Bream, Yelloweye Mullet, Sea Mullet, Silverfish (*Atherinosoma presbyteroides*), Hardyhead (listed as Atherinid sp. but is presumably the Western Hardyhead), South West Goby and Blue Spot or Swan River Goby. Brearley (2005) adds that other species, including Tarwhine, Cobbler (presumably *Cnidoglanis macrocephalus*), Australian Herring and flathead sp. are also caught by recreational anglers in the river.

Introduced Fishes

The Donnelly River catchment has records of Eastern Mosquitofish (*Gambusia holbrooki*) and Redfin Perch (*Perca fluviatilis*) from a few locations (see Morgan *et al.* 1998) while Rainbow Trout (*Oncorhynchus mykiss*) are fairly prolific within the catchment (Figure 11).

DISCUSSION

NATIVE FRESHWATER FISHES

The Donnelly River catchment (including Lakes Jasper, Wilson and Smith) was found to house all eight endemic freshwater fishes of the South-western Australian Drainage Division. A number are known to be rare or restricted. The Salamanderfish has a very restricted distribution, occurring in pools from Augusta to just east of Walpole (Morgan *et al.* 1998). The species is characteristically found in tannin stained, acidic, ephemeral pools in heath land associated with the peat flats (Christensen 1982, Morgan *et al.* 1998). The Blackstripe Minnow is very restricted in geographical distribution and also in the habitat types that it occupies. Along with the

Salamanderfish, it is generally restricted to ephemeral pools along the south coast between Augusta and Walpole although disjunct populations have been recorded (Morgan *et al.* 1998, Morgan and Gill 2000). The Western Mud Minnow is one if the rarest of the south-west's endemic fishes having a fragmented distribution. For example, an isolated population of the species is found in the Moore River catchment near Gingin, the next nearest population being in the upper headwaters of Margaret River (Morgan *et al.* 1998). Specimens of the Balston's Pygmy Perch from Moore River are housed in the Western Australian Museum and Pen (1999) reports one individual from the Collie River. Its range has been severely fragmented by habitat change and they are now found from the upper reaches of Margaret River east to the Angove River.

More common endemic freshwater fishes were also recorded in the Donnelly River catchment. The Freshwater Cobbler has a relatively sporadic and unusual distribution within south-western Australia and is characteristically found in large waterbodies such as the main channel of rivers and/or dams. The Western Minnow is the most widespread and abundant of south-western Australia's endemic freshwater fishes and is known from the Arrowsmith River in the north to the Waychinnicup River in the south-east. It is are found in larger rivers, small streams, lakes and floodwaters and have a diet that consists largely of terrestrial insects. The Lake Jasper population is infected with an introduced cestode (tapeworm), *Ligula intestinalis*. The Western Pygmy Perch is also widespread throughout south-western Australia, from the Arrowsmith River in the north to the Angove River in the south-east. The Nightfish is also comparatively widespread throughout south-western Australia from the Hill River to the Kalgan River. As with the Western Minnow, these latter two species are found in a wide range of freshwater habitats throughout their range (Morgan *et al.* 1998).

ESTUARINE FISHES IN THE DONNELLY RIVER

At the time of sampling the mouth of the river was open and the salinity of the bottom (at Hut 20) was 21.1 ppt while the surface salinity was 1.0 ppt. This salt-wedge was recorded as far upstream as the Boat Landing Rd boat ramp with bottom-water salinity being ~18 ppt with freshwater lying above. While the majority of the estuarine species recorded in the current study were not found beyond the lower estuary or limit of tidal influence, the Western Hardyhead, Swan River Goby and South West Goby are known to penetrate upstream into freshwaters in many of the south-west's rivers (Morgan *et al.* 1998).

Similarly, within the Donnelly catchment, they were all abundant within the freshwaters of Lake Jasper (Morgan *et al.* 1998).

POUCHED LAMPREY

The Pouched Lamprey belongs to the Petromyzontiformes, which are one of the only two surviving groups of the jawless (agnathan) stage in vertebrate evolution (Hardisty 1982). The absence of jaws and paired fins separates the agnathans from the cartilaginous (sharks and rays) and bony (teleosts) fishes. While there are 38 species of extant lampreys, the Pouched Lamprey is the sole member of the Geotriidae and one of only four species of Southern Hemisphere lampreys (Potter 1980). The species is known from south-western and south-eastern Australia, Tasmania, New Zealand and south-western and south-eastern South America (Potter 1996) and in WA it is found in most of the river systems from the Murray River south to approximately the Waychinnicup River east of Albany (Morgan *et al.* 1998).

The life-cycle is complex, with the worm-like larval stage (ammocoete) living in 'burrows' below the substrate where they feed on diatoms, detritus and micro-organisms. In south-western Australia at approximately four years of age (and at approximately 90 mm TL) the ammocoete undergoes metamorphosis with the resultant downstream migrant leaving the river during winter. It is thought that there is a one to two year marine trophic phase, where it presumably feeds on fish and their length increases to approximately 500–700 mm TL. The adult then ceases feeding, re-enters rivers and embarks on an upstream migration (moving predominantly at night) during winter and spring. After spending approximately 15–16 months in the river, when they survive off accumulated fat reserves, the adults spawn and die. During this 15–16 month period in the river the adults mature and the males develop a large gular pouch (hence the name pouched lamprey). An enlargement of the oral disc also occurs during this maturation period.

The strength of the upstream migration of Pouched Lamprey is variable from year to year, and due to their nocturnal migration being in winter they are seldom seen. The sites where ammocoete Pouched Lamprey are found are generally characterised by a high degree of shade and a high abundance of organic material on the substrate; factors that are known to influence larval densities (Potter *et al.* 1986). However, the metamorphosed juveniles (downstream migrants) are most often associated with (buried in) sandy substrates that occur in well-oxygenated waters. The larvae are therefore particularly vulnerable to habitat modification as they rely on well oxygenated non-saline

waters that are characterised by shade and organic matter.

There is substantial evidence that lampreys are declining in numbers; particularly as a result of loss of suitable habitat for the larvae, and this is evident within south-western Australian rivers such as the Blackwood where salinisation and land clearing are causing loss of larval beds.

INTRODUCED FISHES

Prior to 2005 a total of 10 species of introduced freshwater fish was recorded from Western Australia (Morgan *et al.* 2004), with a further two introduced fish species being captured in south-western Australia in the last two years. Approximately 500,000 Rainbow Trout fry were stocked by the Department of Fisheries Western Australia into the Donnelly River between 1999 and 2004, and this figure includes approximately 70,000 fry into both Carey Brook and Barlee Brook. This represents about 20% of all of the Rainbow Trout fry stocked into Western Australian waters. A further 20,500 yearling Rainbow Trout were also stocked during this period, representing ~13% of all yearling Rainbow Trout stocked. Although they are stocked into the freshwaters of the main channel and main tributaries of the system, Rainbow Trout are apparently commonly captured at the mouth of the river system at certain times of the year and were reported from the mouth of the river by Hodgkin and Clarke (1989).

The impact of stocking a large predatory fish such as Rainbow Trout within the Donnelly River has not been assessed. An examination of the stomachs of 20 small Rainbow Trout (<310 mm TL, mean TL = 152 mm) in Carey Brook captured in May 1996 revealed that they preyed on a variety of fauna, but the stomachs were dominated by terrestrial fauna (insects) (35% by volume), freshwater crayfish (13%), dipteran larvae (11%), dipteran pupae (12%) and fish/larval lampreys (4%). The proportion of different prey eaten will no doubt change when considering larger trout (see Tay 2005). The impact of trout stocking in this system needs to be assessed in both the freshwaters and the estuary. The impacts of the other feral species that are found in the system are summarised in Morgan *et al.* (2004), while information on Redfin Perch and Eastern Mosquitofish in W.A. can also be found in Morgan *et al.* (2002) and Gill *et al.* (1999), respectively.

CONCLUSION

The Donnelly River is one of the few systems in south-western Australia that continues to provide refuge for eight of the south-west's endemic fishes. As such, it should be considered important to the State's overall biodiversity. The fact that it also provides a major breeding

ground for the Pouched Lamprey adds to its conservation importance. The development of future management plans for the catchment should take into consideration the importance of this fish assemblage and incorporate them into any ecological monitoring programs. The protection and enhancement of instream and riparian habitat and water quality (particularly salinity levels) will ensure the ongoing sustainability of these populations.

ACKNOWLEDGEMENTS

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BIRDS IN FOUR REMNANT BUSHLAND ISOLATES AND A GARDEN AND THEIR IMPORTANCE TO LARGE ISOLATED RESERVES IN PERTH

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ABSTRACT

The birds of four small, isolated remnant urban bushlands: – Shenton Bushland (21 ha.), Underwood Avenue Bushland (31 ha), Hollywood Reserve (6.5 ha), a small unnamed bushland isolate on Monash Avenue (0.75 ha), and a nearby garden (0.1 ha) in metropolitan Perth are recorded. These four remnants are situated between two of Perth's major bushlands – Kings Park (approximately 267 ha of bushland) and Bold Park (approximately 400 ha of bushland). A total of 46 native bird species was recorded. Nearly half of these species are likely to be dependent upon native bushland, highlighting the importance of urban bushland fragments for the preservation of regional avian biodiversity. In addition, it is likely that many species use the smaller bushlands to disperse between Kings Park and Bold Park. These small bushland fragments may play a key role in maintaining species diversity in the larger iconic bushland reserves.

INTRODUCTION

There are numerous studies on the effects of habitat fragmentation on bird communities and the important role of remnant vegetation in facilitating dispersal between fragments (e.g. Kitchener *et al.* 1982; Saunders and Curry 1990; Saunders and de Rebeira 1991; Ford *et al.* 1995; Miller and Cale 2000; Major *et al.* 2001; Watson *et al.* 2003; Antos and White 2004). While, several studies have documented the birds inhabiting major urban bushland fragments in the Perth metropolitan area (Bold Park, How and Dell 1990; Kings Park, Serventy 1938, Recher 2004), no long-term datasets have been published on the birds inhabiting smaller urban bushland fragments. In this study we list the birds of four urban bushland

remnants and a nearby garden in metropolitan Perth, none of which is more than 900m from its nearest neighbour (Berry and Berry 2008). These remnants are Shenton Bushland (21 ha), an A Class Reserve, sampled over 11 consecutive years between 1994 and 2005. Underwood Avenue Bushland (31 ha), owned by the University of Western Australia, sampled over two years – 1998/1999 and 2000/2001, Hollywood Bushland (6.5 ha), a C Class Reserve sampled in 2001/2002, and a small, unnamed isolate on Monash Avenue (0.75 ha), referred to as the Hospital Bushland, sampled in 2001/2002. The garden in Burwood St. (0.1 ha) was monitored from 1981 to 2007. The four remnants and the garden are situated between two of Perth's major bushlands – Kings Park (approximately 267 ha of bushland) and Bold Park (approximately 400 ha of bushland). As well as providing a record of avifaunal diversity at these sites, our aim was to identify species likely to be reliant on native bushland to maintain a presence in the metropolitan area.

METHODS

For a general account of soils, vegetation, fire history, location of sampling locations and vesting/ownership of the four bushlands see Berry and Berry (2008).

Birds were mainly recorded while doing daily checks of pit-traps set for ground vertebrates. This involved walking the same route along and between pit-trap lines soon after dawn between the months of September to March and recording taxa within sight or hearing distance. No attempt was made to count individuals. At Shenton Bushland, the total number of days sampled over the 11 year span was 1,230. At Underwood Avenue Bushland, sampling was continuous from 17 October 1998 to 14 March 1999 (149 days) and 10 September 2000 to 25 February 2001 (155 days). At Hollywood Reserve, sampling was undertaken between 16 September 2001 and 29 February 2002 (123 days). At Monash Avenue Bushland, sampling was undertaken between 16 September 2001 and 29 February 2002 (123 days). The bird fauna of the garden was recorded opportunistically between 1981 and 2007 (26 years). No attempt was made to quantify bird abundance. In addition, birds were opportunistically recorded in the bushlands on other visits that usually ranged more widely than the transects. Birds flying overhead were not included, apart from Welcome Swallows and Tree Martins.

RESULTS

A total of 50 species was recorded in this study, including 46 native species. These species, together with lists of birds recorded from Kings Park by Serventy between 1928 and 1937 (Serventy 1938) and

by Recher between 1996 and 2002 (Recher 2004), and at Bold Park by Dell (How and Dell 1990) and Birds Australia (1975–2004) are listed in Table 1. (Bird lists for Kings Park include additional taxa not recorded from Serventy and Recher's transects).

Fifty bird species were recorded in Shenton Bushland (26 non-passerine and 24 passerine); 40 species were recorded in Underwood Avenue Bushland (19 non-passerine and 21 passerine); 31 species were recorded at Hollywood Reserve (14 non-passerine and 17 passerine); 15 species were recorded at Monash Avenue Bushland (6 non-passerines and 9 passerine) and 36 species (18 non-passerines and 18 passerine) from the Nedlands garden. Twenty-three (46%) of the taxa recorded at Shenton and Underwood Avenue Bushlands are likely to be dependent on native bushland to maintain a presence or breed in the metropolitan area, and 14 species are represented on the list of "significant birds" of the Swan Coastal Plain in 'Bush Forever' (Government of Western Australia 2000). Notable among these is the Little Eagle, breeding in Underwood Avenue Bushland, and Carnaby's Cockatoo. There is evidence of recent recolonisation of Shenton Bushland with the first records there after a decade of the Variegated Fairy-wren and the Common Bronzewing Pigeon.

DISCUSSION

Serventy (1938) noted that at the time of his first Kings Park bird census between 1928 and 1937, the habitat of Kings Park had already been altered by removal of large trees and clearing, and that this was ongoing, despite its A Class Reserve status. He also noted Kings Park's increasing isolation: "The Park is bounded by the Swan River estuary on the eastern side and houses shut it in along all other boundaries, except for just over a mile on the west where it is continuous with cut-over bush extending across the Perth-Fremantle railway line to the coast". The four discontinuous bushlands which are the subject of this study are all that now remains of this "cut-over bush" connection between Kings Park and the Coast (now represented by Bold Park bushland which has a tenuous connection, particularly to the north in the form of the foreshore reserve).

The Bold Park bird list of How and Dell (1990) and Recher's most contemporary list and review of the status of Kings Park birds (Recher 2004) are included in Table 1. From this it is possible to consider the extent to which Underwood Avenue, Shenton, Hollywood Reserve, and Monash Avenue bushlands are used as "stepping- stones", or potentially may be used, to maintain the native bird assemblage of Kings Park, or even enhance it, should its habitat be restored to a more original state.

Recher (1997) attributes the decline and local extinction of

bird species to change in composition and structure of the Park's native vegetation (particularly loss of the native eucalypt canopy), change in the fire regime, habitat loss on the Swan Coastal Plain and increased isolation. The bushland bird fauna recorded at Bold Park by How and Dell (1990) with 62 taxa, is most representative of the original fauna of the Swan Coastal Plain (see Serventy 1948; How and Dell 1993) with at least seven species still present that had apparently already become extinct in Kings Park by 1928 when Serventy did his first census, or which have subsequently become locally extinct there (Red-capped Parrot, Splendid Fairy-wren, White-browed Scrubwren, Grey Shrike Thrush, Brown-headed Honeyeater, White-naped Honeyeater, Tawny-crowned Honeyeater). Bold Park is therefore a potential source of recolonisation by such species to Kings Park. More importantly, it is also the most likely source of recruitment that may currently enable elements of the present bird assemblage of Kings Park to persist.

Table 1 identifies 34 species that we consider to be reliant on bushlands to maintain a presence or to breed in the metropolitan area. (Mountain and Wood Ducks are included in this list because, although common waterbirds, both were recorded breeding in bushlands and are probably largely dependant on hollows in native vegetation to breed in the metropolitan area). Twenty-one (62 %) of these bush-dependant birds were recorded in Kings Park, Bold Park, Shenton Bushland and Underwood Avenue Bushland. While some of these, such as the Common Bronzewing Pigeon, Purple-crowned Lorikeet and Red-capped Parrot may be potentially capable of reaching Kings Park without access to "stepping stones" of native bushland, their apparently transient presence in Shenton and/or Underwood Bushlands suggests that these bushlands are not large enough to sustain populations. It is likely that others, such as the Rufous Whistler, Grey Fantail, Western Flyeater, Weebill, Yellow-rumped Thornbill, and Black-capped Sittella may be entirely dependant on these intermediate bushlands to reach Kings Park where the status of all these passerines, except the Weebill and Rufous Whistler, is reported to currently be declining (Recher 2004). The Grey Fantail and Painted Button-quail are examples of highly mobile species which require native bushlands to breed in the metropolitan area.

The first recording in a decade at Shenton Bushland of the Variegated Fairy-wren in 2002 and Common Bronzewing Pigeon in 2003 provides evidence of the dynamic nature of bird populations and the potential use of native bushland in recolonization within the metropolitan area. Neither of these species is recorded from Bold

Table 1. Birds recorded at Shenton Bushland (SHB), Underwood Avenue Bushland (UAB), Hollywood Reserve (HR), Monash Avenue Bushland (MAB), a Nedlands garden (NG), Kings Park (KP) (Serventy 1937, and Recher 2004) and Bold Park (BP) (How and Dell 1989). BA = Birds Australia records * = breeding (Shenton Bushland, University Bushland, Hollywood Reserve and Nedlands garden only); ^ = Cousin *et al.* (2000); + = introduced; Shaded = species probably reliant on native bushland to maintain presence or breed in metro. area. E = previously present but now locally extinct; U = status unchanged; I =status increasing; D = status decreasing.

NON-PASSERINE SPECIES	SHB	UAB	HR	MAB	NG	KP			BP	
	1994–2005	1998–2001	2001–02	2001–02	1981–2005	Serventy 1928–37	Recher 1996–2002		How & Dell 1986–89	B.A. 1975–2004
Mountain Duck	✓	✓*								
Wood Duck	✓*				✓					
Black-shouldered Kite	✓	✓					✓	U	✓	✓
Whistling Kite						✓		E		✓
Brown Goshawk	✓	✓	✓		✓	✓	✓	U	✓	✓
Collared Sparrowhawk	✓	✓	✓		✓		✓	U	✓	✓
Little Eagle	✓	✓*					✓	U	✓	✓
Brown Falcon						✓				✓
Australian Hobby	✓	✓	✓		✓	✓		U	✓	✓
Australian Kestrel	✓					✓	✓	U		✓
Stubble Quail						✓				
Painted Button-quail	✓*	✓					✓		✓	✓
Spotted Dove +	✓*	✓*	✓		✓*	✓		D	✓	✓
Laughing Dove +	✓*	✓*	✓		✓*	✓	✓	U	✓	✓

Common Bronzewing Pigeon	✓		✓[5]				✓	I		
Purple-crowned Lorikeet	✓				✓	✓	✓	E		
Rainbow Lorikeet +	✓*	✓*	✓	✓	✓*		✓	I	✓	✓
Ring-necked Parrot	✓*	✓*	✓	✓	✓*	✓	✓	I	✓	✓
Western Rosella									✓[6]	
Red-capped Parrot	✓				✓	✓			✓	✓
Elegant Parrot									✓	
Carnaby's Cockatoo	✓	✓	✓	✓	✓	✓	✓	D	✓	✓
Galah	✓*	✓*	✓	✓	✓		✓	I	✓	✓
Corella spp +	✓*	✓*			✓		✓	U	✓	✓
Sulphur-crested Cockatoo +										✓
Pallid Cuckoo	✓	✓				✓		E	✓	✓
Fan-tailed Cuckoo					✓	✓	✓	U	✓	✓
Shining Bronze Cuckoo						✓	✓	D	✓	✓
Horsfields Bronze Cuckoo						✓	✓	U	✓	
Tawny Frogmouth	✓	✓	✓				✓	U	✓	✓
Barn Owl	✓*								✓	
Boobook Owl	✓		✓^		✓	✓		U	✓	
Fork-tailed Swift						✓		U		✓
Laughing Kookaburra +	✓	✓	✓	✓	✓	✓	✓	U	✓	✓
Sacred Kingfisher	✓	✓			✓	✓	✓	D	✓	✓
Rainbow Bee-eater	✓*	✓	✓	✓	✓	✓	✓	U	✓	✓
Sub-totals	**26**	**19**	**14**	**6**	**18**	**21**	**21**		**25**	**26**

Table 1 (cont.)

PASSERINE SPECIES	SHB	UAB	HR	MAB	NG	KP			BP	
	1994–2005	1998–2001	1998–2001	1998–2001	1981–2005	Serventy 1928–37	Recher 1996–2002		How & Dell 1986–89	B.A. 1975–2004
White-backed Swallow									✓	✓
Welcome Swallow	✓	✓	✓	✓	✓		✓	D	✓	✓
Tree Martin	✓	✓	✓	✓	✓	✓	✓	D	✓	✓
Black-faced Cuckoo-shrike	✓	✓	✓*	✓	✓	✓	✓	I	✓	✓
White-winged Triller							✓	U		
Rufous Whistler	✓	✓*	✓			✓	✓	I	✓	✓
Golden Whistler						✓		E		✓
Scarlet Robin						✓		E		✓
Yellow Robin						✓		E		
Grey Shrike-thrush									✓	✓
Willie Wagtail	✓	✓	✓		✓	✓		D	✓	✓
Grey Fantail	✓	✓*	✓		✓	✓	✓	D	✓	✓
Western Flyeater	✓	✓*	✓			✓	✓	D	✓	✓
Weebill	✓*	✓*	✓			✓	✓	I	✓	✓
Yellow-rumped Thornbill	✓	✓*				✓	✓	D	✓	✓
Broad-tailed Thornbill						✓	✓	E	✓	✓
Western Thornbill						✓	✓	E		✓
Splendid Fairy-wren									✓	✓
Variegated Fairy-wren	✓				✓[1]		✓			
White-winged Fairy-wren									✓	
White-browed Scrubwren									✓	✓

Grey-breasted White-eye	✓	✓			✓	✓	✓	I	✓	✓
Black-capped Sittella	✓	✓*				✓	✓	D	✓	✓
Mistletoe Bird					✓[2]	✓	✓	U	✓	
Striated Pardalote	✓*	✓*	✓	✓	✓	✓	✓	I	✓	✓
Spotted Pardalote	✓	✓				✓	✓	U	✓	✓
Red Wattlebird	✓*	✓*	✓	✓	✓*	✓	✓	U	✓	✓
Little Wattlebird	✓						✓	U	✓	✓
Singing Honeyeater	✓*	✓*	✓	✓	✓*	✓	✓	I	✓	✓
Brown Honeyeater	✓*	✓*	✓	✓	✓*	✓	✓	I	✓	✓
Yellow-plumed Honeyeater						✓		E		
New Holland Honeyeater	✓[3]	✓			✓[3]				✓	✓
Western Spinebill	✓					✓	✓	D	✓	✓
White-cheeked Honeyeater	✓[4]	✓[4]	✓[4]		✓[4]		✓	I	✓	✓
Brown-headed Honeyeater									✓	✓
White-naped Honeyeater							✓	U	✓	✓
Tawny-crowned Honeyeater									✓	✓
White-fronted Chat						✓			✓	✓
Goldfinch +						✓				
Magpie-lark			✓^		✓		✓	U	✓	✓
Dusky Woodswallow						✓		E		
Grey Butcherbird	✓	✓*	✓		✓	✓	✓	U	✓	✓
Australian Magpie	✓	✓	✓	✓	✓	✓	✓	U	✓	✓
Australian Raven	✓	✓	✓	✓	✓	✓	✓	I	✓	✓
Sub-totals	24	21	17	9	18	29	28		34	37
Totals	50	40	31	15	36	50	49		59	63

[1] One record on 8/1/2005; [2] Not recorded since 1982; [3] Recorded since 1998; [4] Recorded since 2000. [5] Recorded 16/7/2005; [6] Now considered an error (J.Dell pers. comm.)

Park although this seems their most likely origin. White-cheeked and New Holland Honeyeaters are comparatively recent regular visitors to Shenton Bushland and the Nedlands garden. The single record of a Variegated Fairy-wren in the garden demonstrates the unexpected mobility of this species. This bird (a male in full breeding colour) was clearly on the move, only stopping momentarily when attracted with a bird caller.

The area that includes the bushlands that are the subject of this paper is part of the daily feeding range of a large population of Carnaby's Cockatoo. Over the last 26 years we have recorded flocks of up to 670 individuals roosting in summer and autumn in north Hollywood, close to the Hollywood Reserve (Berry 2008). Although their daily feeding range is not known, these bushlands must provide a significant proportion of the daily food requirements of what represents a very substantial avian biomass. The use of the 0.75 ha. Monash Avenue Bushland by Carnaby's Cockatoo, where it feeds on *Banksia* and *Allocasuarina*, demonstrates that even the smallest of bushlands contribute to a larger collective food resource and the persistence of this large, mobile species in the metropolitan area.

In conclusion, preservation of the biodiversity and composition of the bird assemblages currently present in Perth's western suburbs, which includes Kings Park and Bold Park, two of the City's largest and most iconic nature reserves, is likely only to be maintained in the long term, if the existing remnant bushland between them is preserved. This should include not only Shenton and Underwood Bushlands, Hollywood Reserve and Monash Avenue Bushland, but native bushland and the existing native eucalypts on adjacent State (Health Department; Water Corporation), Commonwealth (Defence force) and private land (Bedbrook Place). There is probably still the opportunity to create a viable linkage of native vegetation between Kings Park and Bold Park

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A NEW SUBSPECIES OF *LOXOCARYA STRIATA* (RESTIONACEAE) FROM THE WHICHER RANGE

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ABSTRACT

Loxocarya striata subspecies *implexa* Keighery is described and illustrated. This newly described taxon is the fifteenth endemic of the ironstone soils at the base of the Whicher Range, south-east of Busselton.

INTRODUCTION

Over the past decade the Western Australian Department of Environment and Conservation (previously the Department of Conservation and Land Management) has undertaken intensive floristic and reserve surveys of the Swan Coastal Plain (Gibson *et al.* 1994, Keighery 1999). Currently these surveys are continuing under a new program entitled "Swan Bioplan" and have been extended to include the Darling and Whicher Escarpments of their respective ranges.

During these surveys a very distinctive vegetation community was described (Gibson *et al.* 1994) from shallow red clay soils over ironstones south-east of Busselton at the base and foothills of the Whicher Range. This community comprised tall shrublands of *Dryandra squarrosa* subsp. *argillacea*, *Calothamnus* sp. (Whicher) and *Hakea oldfieldii* over open to dense low shrublands over tall sedges over dense herbs.

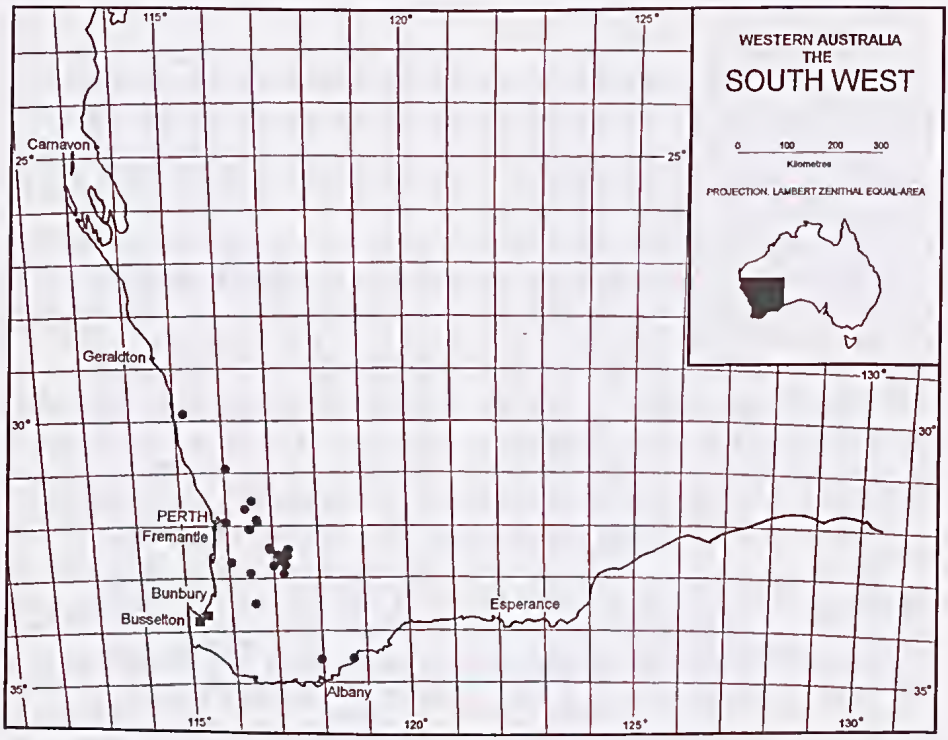
This and subsequent surveys have also uncovered a series of localised endemic plants on these soils, namely: *Andersonia ferricola* ms, *Calytrix* sp. Tutunup (G. Keighery et N. Gibson 2953), *Brachyscias verrucundus*, *Chamelaucium roycei* ms, *Darwinia* sp. Williamson (G. Keighery 12717), *Dryandra squarrosa* subsp. *argillacea*, *Dryandra nivea* subsp. *uliginosa*, *Gastrolobium modestum*, *Gastrolobium papilio*, *Grevillea elongata*, *Grevillea maccutcheonii*, *Hakea oldfieldii*, *Petrophile latericola* ms and *Stylidium ferricola*. The community and many of the constituent taxa are listed as endangered or rare

under State and Federal acts. This paper describes another localized endemic of this habitat.

One taxa uncovered during these surveys was an unusual member of the genus *Loxocarya*. The *Loxocarya* populations found on the Ironstones were referable to *L. striata*, which was previously a member of the genus *Megalotheca*, but has been placed in a re-circumscribed *Loxocarya* (Briggs and Johnson 2001a &b).

The ironstone populations differ in being smaller in floral and vegetative measurements (Meney *et al.* 1999). Both taxa occur on skeletal soils over laterite or ironstone and both are apparently obligate seeders. The habitat of *Loxocarya striata* subsp. *implexa* is markedly different in often being waterlogged in spring. These populations are also allopatric to the main range of the species (Map 1). This combination of morphological and habitat characters are considered worthy of recognition at a subspecific level.

This paper forms part of a continuing series (Keighery 1997, 1998, 2001a&b) documenting the



Map 1. Distribution of *Loxocarya striata showing Loxocarya striata* (F. Muell.) B.G. Briggs & L.A.S. Johnson subsp. *striata* (circles). *Loxocarya striata* subspecies *implexa* Keighery (squares).

taxonomic outcomes of the above surveys, by describing this new subspecies. It is the third paper in a series on the flora and vegetation of the Whicher Range (Keighery *et al.* 2008, Keighery 2008).

TAXONOMY

Key to *Loxocarya* (From Pate and Meney 1999)

1. Fruit heart shaped (bilocular), styles 2 2
1. Fruit unilocular, style 1 ..... *L. magna*
2. Tufted plants, densely packed culms on erect or shortly creeping rhizomes 3
2. Clonal plants, widely spaced culms on stout spreading rhizomes ..... *L. cinerea*
3. Culms 2 mm or less in diameter at base, less than 1 metre tall, female spikelets 2-many per culm, 7–10 mm long 4
3. Culms 3–4 mm in diameter at base, 2 metres tall, female spikelets 1–3 per culm, 30–50 mm long ..... *L. gigas*
4. Culms 0.8–1 mm diameter at base, twisted and freely branched throughout 5
4. Culms 1–2 mm diameter, straight or sparingly branched at top ..... *L. albipes*
5. Plants forming large clumps to 1 metre tall from creeping rhizome, 3–4 mm diameter ..... *L. striata* subsp. *striata*
5. Plants forming compact dense clumps to 40 cm tall from short rhizome, c. 2 mm diameter ..... *L. striata* subsp. *implexa*

Description of species

Loxocarya striata (F. Muell.) Briggs et Johnson **subsp. *implexa*** G.J. Keighery *subsp. nov.* (Figure 1 and 2)

Inter species *Loxocarya striata* stature minore distinguitur, rhizomata 2 mm diametro, culmi ad 20–40 cm longi, spicae femineae 4–5 mm longa; fructus 5–6 mm longi.

Typus: Williamson Road, Whicher Range, 16 March 1991, G.J. Keighery 12060,a (holo: PERTH male plant, iso: to be distributed).

Plants dioecious forming small rounded clumps of numerous erect to spreading culms from interlaced short slender rhizomes, 1–2 cm deep, to 20 cm long, 1.8–2 mm diameter, orange brown with white hairs when young. Culms, hollow, light green, 20– 40–(50) cm long, sinuose and branched throughout, striate, 1–1.2 mm diameter at base. Culm sheaths appressed, red-brown, 8–10 mm long, lamina 3–3.3 mm long. Culms bearing numerous elongate spikelets, widely spaced on branched culms. Male spikelets 3–5 mm long. Female spikelets few per culm, 4–5 mm long, enlarging to 5–6 mm long and 5 mm wide in fruit. Fruit a heart shaped capsule, 5–6 mm long with a prominent persistent stylar beak.

Figure 1. Male flowering culms of *Loxocarya striata* subsp. *implexa*. Voucher G. Keighery 12060a (PERTH). Scale bar =1 cm.

Figure 2. Female flowering culms of *Loxocarya striata* subsp. *implexa*. Voucher G. Keighery 12060b (PERTH). Scale bar =1 cm.

Other specimens examined. WESTERN AUSTRALIA: Treeton, FV 2089, 33° 47' S 115° 17' E, 7 Nov. 1983, G.S. McCutcheon 1044 (PERTH); Williamson Road, Whicher Range, 33° 42' S 115° 38' E, 16 March 1991, G.J. Keighery 12060,b (female PERTH);

Distribution. Foothills of the Whicher Range south-east of Busselton (Map 1). On the interface between the Swan Coastal Plain IBRA region and the Jarrah Forest (Thackway and Creswell 1995).

Habitat. Recorded as occurring on shallow yellow sands and shallow red clays over massive ironstones.

Flowering Period. Flowering recorded from March to April, probably before the first winter rains. Mature fruits and seeds produced as flowering ends.

Conservation Status. The subspecies is naturally very localised but has a large population in Willcox Forest Block. Potentially endangered by mineral sand mining and hydrological change via water extraction for mining, agriculture or urban uses.

Etymology. The specific name denotes the intricately interbranched culms.

DISCUSSION

This subspecies differs from the nominate subspecies of *L. striata* in the dimensions of almost all vegetative and floral features. Plants are much smaller and more densely compact than *L. striata*, being up to 50 cm tall compared to 60cm to over 1 metre. Consequently the rhizome of this subspecies is 20 cm long and 2 mm wide compared to 40 cm long versus 3–4 mm wide. The culms of *L. striata* subsp. *implexa* are 20–40 cm long, compared to 60–120 cm long. Fruits are also smaller (5–6 mm long compared to 10–12 mm long).

This is the fifteenth taxon endemic to the Busselton Ironstones habitat (which themselves were only documented in the 1990's), of which ten have now been formally described.

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Figures one and two were drawn by Nadine Guthrie.

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OBITUARY

ANN GOODALE (1937-2007)

Ann Goodale was born Ann Thornton on 23 March 1937 in Clevedon (near Bristol) in England. She was the third of five siblings and has an older sister Betty and brother John, and a younger brother and sister Alan and Janet who are twins.

Ann's father was a doctor and the family migrated to Australia for a new life after the Second World War. They moved first to Sydney and soon after to Western Australia where the family spent their first year in Mount Magnet before moving to Lesmurdie, Perth and then Fremantle.

Ann never went to school. She was taught at home by her mother and was involved in a family theatre group the "Mayflower Troup". She later worked in family shops in Fremantle. As a young woman Ann put herself through university, achieving a double major in Literature and Ancient Greece at the University of Western Australia. Ann's first day in school was as an English teacher and she taught at various high schools including Geraldton, City Beach, Kwinana and Rockingham Senior High with the last ten years of her career as Senior Mistress.

Ann's enthusiasm, friendliness and knowledge attracted people. She was not raised in a religious

Ann on holiday at Berry Farm cafe, with Willie Wagtail.

Ann radio tracking Little Penguin, Warnbro Sound.

family, but as an adult chose the Christian faith and the Anglican Church. She especially loved singing hymns at St George's in Safety Bay.

Ann was married to Bob Goodale on 30 November 1973 at Palmyra and lived since then at their home in Arcadia Drive Safety Bay. Ann and Bob formed a film and photography company ACE Films (Australasian Animal Conservation and Environment Films). Together they made many award winning wildlife documentaries and won many awards. Ann wrote numerous children's books, illustrated with Bob's photos. Together they wrote hundreds of newspaper and popular magazine articles on environment issues.

Twenty seven years ago Ann and Bob purchased 100 acres of native bush, "Goodale Sanctuary", at Coolup near Pinjarra. There they shared many wonderful times with native flora and fauna including rare and endangered orchids, more than 100 species of birds, bandicoots and possums. Many Naturalist Club "camp outs" were held there as well as excursions by other societies and clubs. Ann was elected an honorary life member of the WA Naturalists' Club in 1999 for her outstanding commitment and dedicated

Ann with Brahminy Kite, Raptor Centre, Margaret River.

work for conservation. Remnant bush seminars and research on bush management resulted in a Greening W. A. award being granted for their reserve in 1995.

When Ann retired from teaching 10 years ago Ann and Bob's shared passion for the environment was expressed in the development of the multi award winning Naragebup Rockingham Regional Environment Centre, a special community-owned and run, educational asset in Rockingham.

Although Ann suffered from a life-long lung disease she was physically active, enjoying abseiling, canoeing, caving and camping. Her artistic nature was expressed in her love of theatre and appreciation of beautiful music. She read books every day, often three books at a time and had her own library of thousands of pre-loved books. Breathing was difficult for her during the last twelve months, but she faced life and death with courage.

During her final days Ann said she was at peace with God and loved everybody. She was able to say goodbye to friends and family and passed into eternity in the early hours of Sunday morning, 19 August 2007, aged 70 years and 4 months.

Ann Goodale lived a very fruitful life and will be sadly missed by her husband, grandchildren, family, and friends and by the conservation movement.

– Rev. BOB HOSKEN and BOB GOODALE

Southern Giant Petrel with a geolocator and colour band recovered on Rottnest Island – On 6 September 2007 I found the tarsus and foot of a large seabird (Figure 1) on a firebreak at the west end of Pink Lake, Rottnest Island. At the time I was accompanied by Vee Saunders and Bert Genat (Rottnest Island Authority). The tarsus and foot were the only remains of the bird on the firebreak. The tarsus had a yellow colour band on it. Attached to the colour band was a geolocator. Both the colour band and the geolocator were in good condition. Written on one side of the geolocator was the following (Figure 1):

ins@bas.ac.uk
1266
MK4

On the other side was:

ATMEL436
24C1024W
S127

I contacted the Australian Bird and Bat Banding Scheme with the details of the find. They then contacted the British Antarctic Survey (BAS) via the email address. The BAS reported that the bird was a Southern Giant Petrel *Macronectes giganteus* which had been banded as a nestling on 19 April 2007 on Bird Island, South Georgia, Antarctica (54deg 1min S; 38deg 3 min W). It

Figure 1. Tarsus and foot of the banded Southern Giant Petrel found near Pink Lake, Rottnest Island and below the geolocator removed from the colour band.

was one of 27 fitted with geolocators that season and had travelled at least 10000kms in the 4 months since it had been banded. I assume that the bird had been blown ashore during a storm and the tarsus and foot taken inland by a Raven *Corvus coronoides*.

The BAS informed me that the geolocator has a clock and records daylight intensity at regular intervals. It also has a salt water switch which records when the bird settles on the water. The device is capable of recording for up to 3 years. From the time of sunrise to sunset the logger can provide a rough estimate of longitude. From the total day length an estimate of latitude can be made. From these data the bird's passage can be plotted and the length of time spent on the water can also be found.

This is the second banded Southern Giant Petrel I have recovered on Rottnest Island. The first was found on 8 July 1986 and had been banded by Brazilians at Stinker Point, Elephant Island, South Shetlands. The details can be found in Saunders (1987).

REFERENCE

SAUNDERS, DENIS. 1987. Banded Southern Giant Petrel recovered on Rottnest Island. *The Western Australian Naturalist* 17: 19.

– DENIS SAUNDERS, Weetangera, ACT

CLUB NEWS

Programme

General Meetings and Branch Meetings are held at various venues in Nedlands, Kalamunda, Rockingham and North Beach.
The Retired and Leisured Group meets on alternate Wednesdays at 10a.m.
Excursions and field days are planned from time to time and will be advertised in the Club's monthly newsletter "The Naturalist News".

THE WESTERN AUSTRALIAN NATURALIST
(Journal of the W.A. Naturalists' Club)

Editor
MR JOHN DELL

The Western Australian Naturalist publishes original data on all branches of natural science pertaining to Western Australia. Originals and two copies of manuscripts should be submitted to the Editor for review by two referees. Authors are requested to follow current editorial style. If possible, manuscripts should be submitted on an IBM compatible 3½ disk in Word format. High quality illustrations suitable for some reductions in size are preferred.

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Members are reminded that they may make financial contributions to the club. This funding is very important from the Club's point of view, as it helps our publication activities, field station maintenance and other miscellaneous activities. Members are asked to remember the club and its needs when preparing their Wills and Testaments.
The WA Naturalists' Fund is entered in the register of Environmental Organisations. Donations of $2.00 and over are tax deductible under item 1 Section 30-15 and Subsection 30B of the Income Tax Assessment Act 1997.

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Annual Membership: one adult, $60; Double Membership: $75; Family Membership: $65; Young members (6–17 years): $30. All Subscriptions include "The Western Australian Naturalist".
Further copies of "The Western Australian Naturalist" (or back copies) are available from the Treasurer.

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and back copies of

THE WESTERN AUSTRALIAN NATURALIST

A range of Club Handbooks and back copies of the Journal are available. For availability and cost please check the Club's website or contact the Club at the address on the inside cover of this journal.

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